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Distribution recognition for estimated benefit-cost ratios

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DISTRIBUTION RECOGNITION FOR ESTIMATED BENEFIT-COST RATIOS

BY

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INTRODUCTION

> ALL MEN ARE LIABLE TO ERROR; AND MOST MEN ARE, IN MANY POINTS, BY PASSION OR INTEREST, UNDER TEMPTATION TO IT. (52, P. 315)

GOVERNMENTAL EXPENDITURES HAVE BEEN EXPANDING AT AN INCREASINGLY RAPID RATE IN THE UNITED STATES, AND NO INDICATION HAS BEEN PROVIDED THAT THIS TREND WILL BE CURTAILED IN THE NEAR FUTURE. DURING THE YEARS 1953 TO 1954, THE FEDERAL GOVERNMENT DISBURSED ROUGHLY $140 BILLION, APPROXIMATELY THE SAME AMOUNT THAT WAS SPENT IN THE ENTIRE 140 YEAR PERIOD FROM 1789 TO 1929 (44, P. 13), AND THE PRESIDENT'S BUDGET FOR THE FISCAL YEAR 1964 HAS CALLED FOR A DISBURSEMENT OF ALMOST THAT AMOUNT IN A SINGLE YEAR ALONE (94, P. 9). WHILE IT IS TRUE THAT CHANGES IN PRICE LEVELS OVER THE YEARS TEND TO BLUNT SUCH A COMPARISON, THE UNAVOIDABLE FACT REMAINS THAT FEDERAL, STATE AND LOCAL EXPENDITURES STILL ACCOUNT FOR A LARGE TRANSFER OF RESOURCES WITHIN THE ECONOMY.

AS AN EXAMPLE OF THE GROWTH OF GOVERNMENTAL EXPENDITURES IN A SPECIFIC AREA, TABLE 1, PAGE 2, ILLUSTRATES THE MAGNITUDE OF THE FEDERAL GOVERNMENT'S INVESTMENT IN THE DEVELOPMENT OF WATER RESOURCES. IN ADDITION TO THE VALUES SHOWN IN TABLE 1, EXPENDITURES FOR WATER-RESOURCE DEVELOPMENTS HAVE ALSO CONTINUED TO EXPAND OVER THE PAST DECADE. NOT ONLY HAVE OVER FIVE AND ONE-THIRD BILLION DOLLARS BEEN SPENT BY THE BUREAU OF RECLAMATION DURING THE PERIOD 1903 TO 1963, BUT ANOTHER SIX BILLION DOLLARS WILL BE REQUIRED TO COMPLETE THE 136

TABLE 1. THE FEDERAL WATER RESOURCE DEVELOPMENT PROGRAM--APPROPRIATIONS BY DECADES (MILLIONS OF DOLLARS - FISCAL YEARS)[A]

AGENCY	THROUGH -1910	1911 TO 1920	1921 TO 1930	1931 TO 1940	1941 TO 1950	1951 TO 1954	TOTAL
DEPARTMENT OF THE ARMY: CORPS OF ENGINEERS	624.0	347.2	674.8	1,904.0	3,126.9	2,184.5	8,861.4
DEPARTMENT OF THE INTERIOR: BUREAU OF RECLAMATION	62.3	109.3	137.3	506.1	1,397.0	882.8	3,094.8
BONNEVILLE POWER ADMINISTRATION				27.9	167.2	241.2	436.3
SOUTHWESTERN POWER ADMINISTRATION					8.0	23.6	31.6
SOUTHEASTERN POWER ADMINISTRATION						5.4	5.4
BUREAU OF INDIAN AFFAIRS	7.1	15.2	26.2	36.7	36.1	33.2	154.5
TENNESSEE VALLEY AUTHORITY				220.6	456.0	916.5	1,593.1
DEPARTMENT OF STATE: INTERNATIONAL BOUNDARY AND WATER COMMISSION				15.2	23.7	35.5	74.4
DEPARTMENT OF AGRICULTURE: FLOOD CONTROL AND FLOOD PROTECTION					20.0	27.4	47.4
TOTAL	693.4	471.7	838.3	2,710.5	5,234.9	4,350.1	14,298.9

[A]SOURCE: 97, P. 5.

PROJECTS NOW AUTHORIZED BY CONGRESS FOR CONSTRUCTION (93, P. 1). THE CORPS OF ENGINEERS HAS SUPERVISED OVER ONE BILLION DOLLARS IN CIVIL WORKS DURING 1964 (65, P. 122), A LARGE PERCENTAGE OF WHICH HAS BEEN DEVOTED TO WATER-RESOURCE DEVELOPMENT.

GOVERNMENTAL CAPITAL EXPENDITURES HAVE OFTEN BEEN CHARACTERIZED BY THEIR UNIQUE NATURE WHICH WOULD TEND TO REDUCE THE CERTAINTY OF ACHIEVING A PREDICTED OUTCOME OF THE NET BENEFIT TO THE NATION OF A PARTICULAR INVESTMENT. THE PRESENCE OF AN UNCERTAIN ENVIRONMENT SURROUNDING THE PREDICTION OF SUCH A FINAL OUTCOME HAS BEEN EVIDENCED BY THE EXISTENCE OF DEVIATIONS OF THE ACTUAL COSTS AND BENEFITS ATTRIBUTAL TO AN INVESTMENT FROM THE ORIGINAL ESTIMATES OF COSTS AND BENEFITS MADE DURING A FEASIBILITY STUDY. FOR EXAMPLE, FOR THE 1961 FISCAL YEAR, THE ACTUAL COSTS OF SPACE AND MISSILE CONTRACTS GENERALLY EXCEEDED THEIR ESTIMATED VALUES BY 300 TO 1000 PER CENT. THIS RESULTED IN APPROXIMATELY FORTY PER CENT OF THE GOVERNMENT'S RESEARCH AND DEVELOPMENT BUDGET OF OVER SEVEN BILLION DOLLARS BEING ABSORBED BY COST OVERRUNS (42, P. 2). DEVIATIONS FROM THE ESTIMATED OUTCOMES ALSO HAVE BEEN PREVALENT IN OTHER TYPES OF INVESTMENTS, SUCH AS WATER-RESOURCE DEVELOPMENT PROJECTS.

> "THE ACTUAL COST OF COMPLETED WORKS HAS ALMOST INVARIABLY EXCEEDED THE ORIGINAL ESTIMATES, AND IN THE CASE OF SOME STRUCTURES HAS BEEN TWO OR THREE TIMES AS LARGE. ... IT WAS PARTLY DUE TO A GENERAL INCREASE IN THE COST OF LABOR AND MATERIALS, PARTLY TO UNDERESTIMATES AND AN INSUFFICIENT

> ALLOWANCE FOR CONTINGENCIES, AND PARTLY TO THE NECESSITY OF DOING MORE WORK THAN WAS ORIGINALLY CONTEMPLATED. (104, P. 16)

THE PAST RECORD OF DEVIATIONS FROM ESTIMATED OUTCOMES ASSOCIATED WITH GOVERNMENTAL CAPITAL EXPENDITURES WOULD SEEM TO IMPLY THAT THE DECISION-MAKERS MIGHT HAVE BEEN PROVIDED WITH INADEQUATE OR INACCURATE INFORMATION, INFORMATION WHICH SERVED AS A BASIS FOR THE ALLOCATION OF AVAILABLE CAPITAL. IF THIS IMPLICATION WERE TRUE, THEN FUNDS MIGHT HAVE BEEN APPORTIONED IN A MANNER WHICH DID NOT PROVIDE THE MAXIMUM RETURN TO THE PUBLIC FROM ITS INVESTMENT.

THIS RECORD OF DEVIATIONS FROM ESTIMATED COSTS, ESPECIALLY IN THE AREA OF WATER-RESOURCE DEVELOPMENT, PROVIDED THE ORIGINAL MOTIVATION FOR THIS INVESTIGATION. THE PLAN OF THIS INVESTIGATION HAS BEEN TO INQUIRE INTO THE UNCERTAINTY ASSOCIATED WITH THE ESTIMATES OF BENEFITS AND COSTS USED IN THE JUSTIFICATION OF GOVERNMENTAL CAPITAL EXPENDITURES AND TO DETERMINE THE INFLUENCE OF THE ACCUMULATION OF THESE UNCERTAINTIES UPON ONE OF THE DECISION CRITERIA NOW USED EXTENSIVELY BY GOVERNMENTAL UNITS, THE BENEFIT-COST RATIO. IT HAS BEEN THE CONTENTION OF THIS STUDY THAT MANY OF THE VARIATIONS FROM ESTIMATED OUTCOMES EXHIBITED BY GOVERNMENTAL INVESTMENTS HAVE BEEN A NATURAL RESULT OF THE DISTRIBUTION OF POSSIBLE OUTCOMES ASSOCIATED WITH THE MAJORITY OF PREDICTIONS OF EVENTS WHICH TAKE PLACE AT SOME FUTURE TIME. ONLY THROUGH THE RECOGNITION OF THIS DISTRIBUTION OF OUTCOMES MAY THE DECISION-MAKER EFFECTIVELY ALLOCATE THE RATIONED

CAPITAL AT HIS DISPOSAL AMONG THE VARIOUS COMPETING INVESTMENTS.

AFTER DEFINING THE BENEFIT-COST RATIO IN GENERAL TERMS AND DISCUSSING RISK AND UNCERTAINTY AS THEY AFFECT THE ESTIMATES OF BENEFITS AND COSTS, A MEASURE OF COMPONENT VARIATION, THE CONTINGENCY INDEX, WAS DEVELOPED. THE CONTINGENCY INDEX RELATED THE VARIATIONS IN THE BENEFIT AND COST COMPONENTS TO THEIR EFFECT UPON THE VARIATION IN THE BENEFIT-COST RATIO AND ALSO DESCRIBED THE CHARACTERISTICS OF A DISTRIBUTION OF POSSIBLE BENEFIT-COST RATIO OUTCOMES, A DISTRIBUTION WHICH COULD BE OBTAINED FROM ANALYSIS OF HISTORICAL BENEFIT AND COST ESTIMATION DATA. THE DISTRIBUTION CHARACTERISTICS DERIVED FROM AN ANALYSIS OF HISTORICAL DATA USING THE PROPOSED METHOD ASSOCIATED WITH THE CONTINGENCY INDEX WAS INTENDED TO ALLOW THE ANALYST TO MAKE INFERENCES ON THE TRUE MEAN AND VARIANCE OF THE DISTRIBUTION OF A BENEFIT-COST RATIO ESTIMATED FOR A PROPOSED EXPENDITURE.

IN ORDER TO TEST THE USEFULNESS OF THE PROPOSED METHOD OF PREDICTING THE DISTRIBUTION OF AN ESTIMATE, AN ANALYSIS HAS BEEN MADE OF PROJECTS CONSTRUCTED BY THE BUREAU OF RECLAMATION, PROJECTS WHICH WERE INITIALLY AUTHORIZED PRIOR TO 1939. THESE PROJECTS WERE CHOSEN SO AS TO PROVIDE A LONG ENOUGH SPAN OF TIME FOR THE PROJECT TO REACH A MATURE DEVELOPMENT. DATA HAVE BEEN OBTAINED, WHENEVER POSSIBLE, FROM THE ORIGINAL AUTHORIZATION DOCUMENTS AND THE RECORDS OF THE BUREAU OF RECLAMATION AND HAVE BEEN COUPLED WITH ADJUSTMENTS INTENDED TO

REDUCE THE ACTUAL AND ESTIMATED VALUES OF COSTS TO A COMMON POINT IN TIME AND A COMMON UNIT OF VALUE. THESE DATA PROVIDED THE BASIS FOR THE DETERMINATION OF THE DEGREE OF VARIATION FROM THE ESTIMATED VALUES EXHIBITED BY PREVIOUS INVESTMENTS.

THIS INVESTIGATION ALSO RECOGNIZED THE POSSIBILITY OF THE UNAVAILABILITY OF HISTORICAL DATA WHICH ARE NECESSARY FOR THE DETERMINATION OF DISTRIBUTION CHARACTERISTICS USING THE CONTINGENCY INDEX METHOD. IN SUCH A CASE, THE MEAN AND VARIANCE OF A DISTRIBUTION OF POSSIBLE OUTCOMES OF AN ESTIMATED BENEFIT-COST RATIO MIGHT STILL BE DETERMINED BY THE USE OF MULTIVALUED ESTIMATES, A METHOD WHICH WOULD BE AN ADAPTATION OF THE PERT ACTIVITY SCHEDULING TECHNIQUE.

SEVERAL LIMITATIONS HAVE BEEN PLACED UPON THIS STUDY. THE FIRST LIMITATION WAS THE ACCEPTANCE OF THE BENEFIT-COST RATIO AS A VALID DECISION CRITERION. WHILE THE VALIDITY OF THIS CRITERION HAS BEEN DEBATED BY MANY AUTHORS, THE BENEFIT-COST RATIO HAS BEEN RELIED UPON AS A GUIDE FOR THE JUSTIFICATION OF PROPOSED PROJECTS BY MANY DIVERSE GOVERNMENTAL BODIES. THE BENEFIT-COST RATIO HAS SERVED GOVERNMENTAL BODIES AS BOTH A TEST FOR ACCEPTANCE AND AS A DEVICE FOR PRIORITY RANKING OF PROPOSED INVESTMENTS; YET IMPROVED ANALYSIS SHOULD RESULT FROM CONSIDERING THE RANGE OF POSSIBLE DEVIATIONS ASSOCIATED WITH BENEFIT-COST RATIOS IN EITHER OF THESE FUNCTIONS.

THE SECOND LIMITATION WAS A DIRECT RESULT OF THE ACCEPTANCE OF THE BENEFIT-COST RATIO. THE VALIDITY OF ALL COMPONENTS COMPRISING THE BENEFIT-COST RATIO HAS BEEN ACCEPTED

INCLUDING THE INTEREST RATE, ESTIMATED ECONOMIC LIFE, AND THE VARIOUS COMPONENTS OF BENEFITS AND COSTS INCLUDED IN THE RATIO. THE PURPOSE OF THIS INVESTIGATION WAS TO STUDY THE VARIATIONS IN THE ESTIMATED VALUES RATHER THAN THE APPROPRIATENESS OF THE INDIVIDUAL VALUES ESTIMATED.

LITTLE CONSIDERATION HAS BEEN GIVEN TO QUESTIONS CONCERNING THE BASIC PHYSICAL DATA WHEN TESTING THE CONTINGENCY INDEX ON EXPENDITURES MADE BY THE BUREAU OF RECLAMATION; TO QUESTIONS ABOUT THE ACCURACY OF HYDROLOGIC DATA; OR TO EFFECTS OF PUTTING SOME SPECIFIED AMOUNT OF WATER ON THE SOIL. OTHER TOPICS WHICH WERE OMITTED WERE THE QUESTION OF THE VALUE OF WATER IN ALTERNATIVE USES, THE SUBSIDY PROVIDED TO THE LAND-OWNERS THROUGH INTEREST-FREE REPAYMENT CONTRACTS, AND THE EFFECT OF THE CONSTRUCTION OF RECLAMATION PROJECTS UPON THE REGIONAL OR NATIONAL ECONOMY. WHILE SUCH TOPICS ARE IMPORTANT IN AN ANALYSIS OF THE RECLAMATION PROGRAM ITSELF, THEY WERE OUTSIDE THE SCOPE OF THIS STUDY.

THE SINGLE-VALUED ESTIMATES NOW PROVIDED BY THE ANALYSTS HAVE NOT RECOGNIZED THE IMPORTANCE OF CONSIDERING THE RANGE OF DEVIATIONS FROM THE ESTIMATED VALUE OF THE BENEFIT-COST RATIO USED IN THE JUSTIFICATION OF GOVERNMENTAL CAPITAL EXPENDITURES. THUS, THROUGHOUT THIS STUDY, THE NECESSITY OF THE DECISION-MAKER'S COGNIZANCE OF THE DISTRIBUTION OF POSSIBLE VALUES ASSOCIATED WITH ANY ESTIMATE HAS BEEN EMPHASIZED.

BENEFIT-COST RATIO

> THE EXTENT TO WHICH PEOPLE ACT WITH A CLEAR IDEA OF THEIR ENDS, KNOWING WHAT EFFECTS THEY ARE AIMING AT, IS EASILY EXAGGERATED. ... TO A VERY GREAT EXTENT PEOPLE DO NOT KNOW WHAT THEY ARE DOING UNTIL THEY HAVE DONE IT, IF THEN. (R. G. COLLINGWOOD, THE IDEA OF HISTORY AS QUOTED BY 50, P. 142)

ONE WAY OF REFUTING SUCH A STATEMENT WOULD BE TO HAVE CLEAR OBJECTIVES WHICH ARE APPROACHED THROUGH LOGICAL ACTIONS. WHILE THIS STUDY DOES NOT INTEND TO COMMENT UPON ESTABLISHED GOALS OF A GOVERNMENTAL UNIT, IT DOES SEEK TO IMPROVE UPON THE METHODS USED IN REACHING THOSE GOALS. THUS, AN INQUIRY HAS BEEN MADE INTO A FACET OF THE RECOGNIZED DECISION CRITERIA USED BY NONPROFIT ORGANIZATIONS IN THE DETERMINATION OF WHICH PROJECTS, IF ANY, SHOULD BE AUTHORIZED AND RECEIVE APPROPRIATIONS DURING ANY GIVEN PERIOD OF TIME.

DISCUSSION OF CRITERIA

A CRITERION IS OFTEN REFERRED TO AS A DEFINITE TEST OF PREFERREDNESS; HOWEVER, CONSIDERING THE INTANGIBLES AND UNCERTAINTIES WHICH MAY BE ASSOCIATED WITH A PROPOSAL OF SOME FUTURE ACTION, THE WORD CRITERION MUST MEAN SOME PARTIAL TEST, A TEST WHICH PROVIDES A SIGNIFICANT BASIS OF COMPARISON OF POLICIES, YET, WHICH DOES NOT EMBRACE ALL RELEVANT CONSIDERATIONS. ALSO, ENDOGENOUS AND EXOGENOUS VARIABLE ASSOCIATED WITH ANY MODEL SEEKING TO PORTRAY AN ACTUAL SITUATION ARE USUALLY SO NUMEROUS AND ILL-DEFINED THAT AN ANALYSIS LEADING TO AN ULTIMATE TEST MIGHT VERY WELL PROVE MEANINGLESS. THUS,

WHEN THE WORD CRITERION IS USED, THE READER SHOULD KEEP IN MIND THAT REFERENCE IS MADE TO SOME MEASURE ESTABLISHED IN FULL RECOGNITION OF ITS LIMITATIONS.

CRITERIA USED IN EVALUATING FEDERAL CAPITAL EXPENDITURES SHOULD (A) RANK PROJECTS IN THE SAME FIELD ACCORDING TO SOME MEASURE OF PREFERREDNESS, (B) COMPARE PROJECTS IN DIFFERENT FIELDS, AND (C) DETERMINE THE PROPER EXPENDITURE LEVELS FOR EACH OF THE VARIOUS FEDERAL PROGRAMS (15, P. 273). ONE MIGHT SPECIFY THE TEST OF PREFERREDNESS MENTIONED IN (A) AS ONE WHICH WOULD RANK THE PROJECTS ACCORDING TO SOME SCALE OF SOCIAL BENEFIT AND THEN ADHERE TO A POLICY THAT SOCIAL BENEFIT SHOULD BE MAXIMIZED.[1] EXISTING ECONOMIC ANALYSES, IN GENERAL, PROVIDE MEASURES WHICH WOULD SATISFY THE FIRST CONDITION

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[1]THE BUREAU OF RECLAMATION SEEKS TO MAXIMIZE SOCIAL BENEFITS, DEFINED BY THE BUREAU AS FAMILY FARM OPPORTUNITIES, WHEN ESTABLISHING THEIR RECLAMATION PROJECTS. SUCH A POLICY IS CONTRARY TO THE ECONOMIC THEORY PERTAINING TO INCREMENTAL ANALYSIS IN WHICH THE RETURN ON THE INVESTMENT IS MAXIMIZED BY INVESTING FUNDS IN A PROJECT UNTIL THE POINT IS REACHED WHERE THE MARGINAL COST EQUALS THE MARGINAL REVENUE. BY USING INCREMENTAL ANALYSIS, THE DECISION-MAKER MAY ELIMINATE UNECONOMICAL SEGMENTS OF A PROJECT WHICH WOULD TEND TO REDUCE THE RETURN OF THE MORE PROFITABLE PORTIONS. THE DESIRABILITY OF THINKING IN TERMS OF SEPARABLE SEGMENTS OR INCREMENTS HAS BEEN RECOGNIZED BY THE SUBCOMMITTEE ON EVALUATION STANDARDS (122, P. 5); HOWEVER, THIS THINKING HAS NOT BEEN INCORPORATED INTO AGENCY PRACTICE.

THE BUREAU OF RECLAMATION WOULD BE SEVERELY CONSTRAINED IN AN ATTEMPT TO MAXIMIZE ITS RETURN ON INVESTMENT FROM A NATIONAL POINT OF VIEW, BY EXISTING STATE WATER ALLOTMENT QUOTAS FOR THE VARIOUS RIVER BASINS; HOWEVER, SUCH CONSTRAINTS WOULD NOT PRECLUDE INCREMENTAL ANALYSIS. IT MUST BE RECOGNIZED, THOUGH, THAT UNDER PRESENT POLICIES OF MAXIMIZING FAMILY OPPORTUNITIES, PROJECTS ARE USUALLY EXPANDED BEYOND THEIR OPTIMUM POINT OF DEVELOPMENT RELATIVE TO THE MAXIMIZATION OF RETURN, A POLICY THE CONTROL OF WHICH LIES WITH CONGRESS AND NOT WITH A PARTICULAR FEDERAL AGENCY.

MENTIONED. UNFORTUNATELY, DUE TO PROCEDURAL AND PHILOSOPHICAL DIFFERENCES AMONG VARIOUS GOVERNMENT AGENCIES, EXISTING INDICATORS OF SOCIAL BENEFITS ARE NOT COMPARABLE, AND THUS CONDITION (B) IS NOT NOW BEING SATISFIED. FINALLY, NO EXISTING MEASURE SATISFIES CONDITION (C) AND SUCH DECISIONS REMAIN WITHIN THE CONGRESSIONAL DOMINION.

IN SUMMARY THEN, A DECISION CRITERION SHOULD ADHERE TO THE FOLLOWING PRINCIPLES:

> 1. THE GOODS OR SERVICES TO BE PRODUCED BY A PROJECT HAVE VALUE ONLY TO THE EXTENT THAT THERE WILL BE A NEED AND DEMAND FOR THE PRODUCT.
> 2. THE MOST EFFECTIVE USE OF ECONOMIC RESOURCES REQUIRED FOR A PROJECT IS MADE IF THEY ARE UTILIZED IN SUCH A WAY THAT THE AMOUNT BY WHICH BENEFITS EXCEED COSTS IS AT MAXIMUM RATHER THAN IN SUCH A WAY AS TO PRODUCE A MAXIMUM BENEFIT-COST RATIO ON SOME OTHER BASIS. ...
> 3. THE PROJECT AS WELL AS ANY SEPARABLE SEGMENT OR INCREMENT THEREOF SELECTED TO ACCOMPLISH A GIVEN PURPOSE SHOULD BE MORE ECONOMICAL THAN ANY OTHER ACTUAL OR POTENTIAL AVAILABLE MEANS, PUBLIC OR PRIVATE, OF ACCOMPLISHING THAT SPECIFIC PURPOSE. THE COST OF MAKING THE PRODUCT OR SERVICE AVAILABLE BY ALTERNATIVE MEANS ESTABLISHES A LIMIT TO THE JUSTIFIED PROJECT INVESTMENT FOR ACCOMPLISHING A SPECIFIC PURPOSE.
> 4. FROM AN ECONOMIC STANDPOINT THE ORDER IN WHICH A NUMBER OF PROJECTS SHOULD BE UNDERTAKEN SHOULD BE BASED ON THEIR RELATIVE EFFICIENCY IN USE OF ECONOMIC RESOURCES. ... [C]ONSIDERATION SHOULD BE GIVEN TO THE RELATIVE SIGNIFICANCE OF THE EFFECTS WHICH CANNOT BE MEASURED IN MONETARY TERMS. IT SHOULD BE RECOGNIZED ALSO THAT THE SELECTION OF A PROJECT FOR DEVELOPMENT MAY CHANGE THE RELATIONSHIP OF REMAINING PROJECTS IN THE ARRAY SINCE THE PROJECT UNDERTAKEN MAY AFFECT THE RELATIVE EFFICIENCIES OF THE REMAINING PROJECTS. (123, P. 5)

THUS, BY PROPER ANALYSIS, COMPARISONS OF ADDITIONS TO THE NATIONAL INCOME TO THEIR RESPECTIVE COSTS SHOULD BE POSSIBLE

IN ORDER TO EVALUATE THE POTENTIAL EFFECTIVENESS OF ANY PROPOSAL. JUST SUCH A COMPARISON IS WHAT THE BENEFIT-COST RATIO STRIVES TO ACCOMPLISH.

CALCULATION OF THE BENEFIT-COST RATIO

THE BENEFIT-COST RATIO IS SIMPLY A DEVICE USED TO ASCERTAIN THE VALUE OF BENEFITS WHICH MAY BE DERIVED FROM EACH DOLLAR OF COSTS. A GENERALIZED EXPRESSION FOR THE BENEFIT-COST RATIO, Z, FOR ANY ALTERNATIVE PROPOSAL, J, COULD BE EXPRESSED BY THE EQUATION:

$$Z_J = F(B_{JT}, O_{JT}, K_{JO}, I, T), \quad J = 1, 2, \ldots, M, \quad T = 0, 1, \ldots, N, \tag{1}$$

WHERE

Z_J = INDEX OF PRESENT WORTH OF ALTERNATIVE J,

B_{JT} = FORECASTED FUTURE ANNUAL BENEFITS ACCRUING OVER THE PERIOD OF ANALYSIS AS A RESULT OF ALTERNATIVE J,

K_{JO} = FIXED INVESTMENT COST OF ALTERNATIVE J AT THE PRESENT TIME,

O_{JT} = FORECASTED ANNUAL FUTURE COSTS OF OPERATION, REPAIR, AND MAINTENANCE OVER THE PERIOD OF ANALYSIS AS A RESULT OF ALTERNATIVE J,

I = INTEREST RATE,

T = PERIOD OF TIME.

EQUATION 1 COULD BE WRITTEN IN A MORE SPECIFIC FORM USING THE SUMMATION OVER THE PROJECT'S LIFE OF EACH YEAR'S COSTS AND BENEFITS. THE EQUATION WOULD THEN APPEAR AS:

$$Z_J = \frac{\sum_{T=1}^{N} \frac{B_{JT}}{(1+i)^T}}{K_{JO} + \sum_{T=1}^{N} \frac{O_{JT}}{(1+i)^T}} \qquad (2)$$

EQUATION 2 PROVIDES THE ANALYST WITH A FIGURE FOR THE BENEFIT-COST RATIO BASED ON THE PRESENT WORTH OF THE ANNUAL BENEFITS AND THE OPERATION AND MAINTENANCE COSTS. IN THIS FORM, THE EQUATION IS IDEALLY SUITED FOR INPUTS REPRESENTING DISSIMILAR ANNUAL COSTS OR BENEFITS. HOWEVER, THE EQUATION GENERALLY USED FOR THE FINAL DETERMINATION OF THE BENEFIT-COST RATIO BY GOVERNMENT AGENCIES EMPLOYS AN AVERAGE ANNUAL ESTIMATE FOR BENEFITS AND OPERATION AND MAINTENANCE COSTS COUPLED WITH AN AMOUNT REPRESENTING THE EQUIVALENT ANNUAL COST OF CONSTRUCTION. THUS THE ASSUMPTIONS ARE MADE THAT THE ANNUAL COSTS AND BENEFITS ARE OR MAY BE MADE TO BE UNIFORM AND THAT THE CONSTRUCTION COSTS OCCUR AT, OR ARE REDUCED TO, A SINGLE POINT IN TIME. THIS TRANSFORMATION OF EQUATION 2 WOULD APPEAR AS:

$$Z_J = \frac{B_{JT}}{K_{JO}\left[\frac{i\,(1+i)^T}{(1+i)^T - 1}\right] + O_{JT}}, \quad J = 1, 2, \ldots, M, \quad T = 0, 1, \ldots, N, \qquad (3)$$

WHERE THE TERM IN BRACKETS IS OFTEN CALLED THE CAPITAL RECOVERY FACTOR.

THE APPLICATION OF THE BENEFIT-COST RATIO TO ANALYSES OF

FEDERAL EXPENDITURE PROGRAMS FOR WATER RESOURCE DEVELOPMENT, FOR EXAMPLE, DEVELOPED SLOWLY. THE NAVIGATION IMPROVEMENT ACT OF 1824 AND THE RECLAMATION ACT OF 1902 PROVIDED FOR SURVEYS AND ENGINEERING REPORTS FOR EACH PROPOSED EXPENDITURE. THESE STATUTES WERE FOLLOWED BY THE RIVERS AND HARBORS ACT OF 1927 AND 1928, WHICH AUTHORIZED THE CORPS OF ENGINEERS TO PREPARE WHAT HAVE BECOME KNOWN AS 308 REPORTS.

> THE PLANS [OF PROPOSED PROJECTS] WERE GENERAL IN NATURE, AND TOGETHER WITH ESTIMATES OF PROJECT COST, WERE BASED LARGELY ON AVAILABLE DATA SUPPLEMENTED BY RECONNAISSANCE SURVEYS. THEY WERE NOT ORIGINAALY INTENDED TO BE A BASIS FOR AUTHORIZING FEDERAL IMPROVEMENT; ALTHOUGH THE REPORTS SET FORTH SPECIFIC PLANS OF IMPROVEMENT AND PROJECTS. ... THE 308 REPORTS WERE, HOWEVER, THE BEST DATA AVAILABLE ON SUCH IMPROVEMENTS AND WERE USED BY CONGRESS AS A BASIS FOR SUBSEQUENT LEGISLATION FOR FLOOD CONTROL AND FOR THE TENNESSEE VALLEY AUTHORITY. (45, P. 18)

FINALLY, THE FLOOD CONTROL ACT OF 1936 ESTABLISHED THE OFTEN QUOTED PRINCIPLE OF COMPARING BENEFITS TO WHOMSOEVER THEY MAY ACCRUE WITH THE ESTIMATED COSTS.[1]

DUE TO THE VARIETY OF STATUTES AFFECTING THE VARIOUS FEDERAL AGENCIES CONCERNED WITH WATER RESOURCES, THE COMPUTATIONAL TECHNIQUES AND THE DEFINITIONS OF WHAT ACTUALLY

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[1]THE BUREAU OF RECLAMATION DID NOT DEVELOP ANY ELABORATE METHODS OF ESTIMATING BENEFITS UNTIL AFTER WORLD WAR II, ALTHOUGH PROJECT CONSTRUCTION COSTS HAD ALWAYS BEEN ESTIMATED. THE BUREAU'S FIRST COMPUTATION OF BENEFITS ATTRIBUTAL TO A PROJECT WERE BASED ONLY ON ESTIMATED INCREASES IN GROSS CROP VALUES (125, P. 44); HOWEVER, SINCE THAT TIME A SYSTEM HAS BEEN DEVELOPED IN WHICH ATTRIBUTAL PROJECT BENEFITS ARE BASED UPON A COMPILATION OF ALL DIRECT BENEFITS SAID TO ACCRUE TO THE FARMERS AND APPROXIMATIONS OF NET INDIRECT BENEFITS SAID TO ACCRUE TO OTHER SEGMENTS OF THE ECONOMY.

CONSTITUTED A BENEFIT OR COST VARIED WIDELY AMONG THE AGENCIES. NOT ONLY WAS SUCH A SITUATION CONFUSING, BUT IT ALSO PRECLUDED ANY INTER-AGENCY COMPARISONS OF BENEFIT-COST RATIOS ASSOCIATED WITH PROPOSED PROJECTS. THE NATURE OF THESE DIFFERENCES MAY BE SEEN IN TABLE 2, PAGE 15. IN AN ATTEMPT TO ALLEVIATE THIS PROBLEM, THE FEDERAL INTER-AGENCY RIVER BASIN COMMITTEE[1] ESTABLISHED A SUBCOMMITTEE ON BENEFITS AND COSTS WHOSE PURPOSE WAS TO FORMULATE MUTUALLY ACCEPTABLE PRINCIPLES AND PROCEDURES FOR DETERMINING BENEFITS AND COSTS ASSOCIATED WITH WATER RESOURCE PROJECTS. THIS SUBCOMMITTEE, SINCE RENAMED THE SUBCOMMITTEE ON EVALUATION STANDARDS, PRODUCED TWO REPORTS WHICH, WHILE NOT FULLY ACCEPTED BY THE VARIOUS AGENCIES, HAVE BECOME SOMETHING OF A LANDMARK IN THE BENEFIT-COST AREA.

AS WITH MOST GENERAL PURPOSE ANALYSIS TECHNIQUES, THE BENEFIT-COST RATIO HAS RECEIVED DIRECT CRITICISM. ANY RATIO ENCOUNTERS THE PROBLEMS OF INTRODUCING BIAS INTO THE FINAL RESULT BY WAY OF MAGNITUDE SIMILARITIES BETWEEN THE NUMERATOR AND DENOMINATOR OF THE RATIO, AND COMPARISONS BETWEEN RATIOS FOUND FOR SEVERAL PROJECTS MAY ALSO BE BIASED BY WAY OF DISREGARDING THE RELATIVE SCALE OF BENEFITS AND COSTS COMPRISING EACH RATIO. IN ADDITION TO THESE DIFFICULTIES, ALONG WITH OTHERS WHICH WILL NOT BE ELABORATED UPON IN THIS

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[1]THE AGENCIES REPRESENTED ON THE FEDERAL INTER-AGENCY RIVER BASIN COMMITTEE WERE THE CORPS OF ENGINEERS, THE DEPARTMENT OF THE INTERIOR, AGRICULTURE AND COMMERCE, THE FEDERAL POWER COMMISSION, AND SUBSEQUENT TO THE WATER POLLUTION ACT OF 1948, THE DEPARTMENT OF HEALTH, EDUCATION AND WELFARE.

Table 2. Comparison of the current practices of the participating agencies in measurement of tangib

Practices to be compared (1)	Corps of Engineers[b] (2)	Department of Agriculture (3)
GENERAL PRACTICES		
1. General basis for measuring and comparing tangible benefits and costs (all agencies give consideration to intangible benefits and costs separately from the tangible benefits and costs which enter into the computed benefit-cost ratio.).	Benefits, measured as savings in costs, reductions in losses or increases in income to beneficiaries, all of which are reduced by the amount of any associated costs other than project costs necessary for their realization, are compared with project costs which consist of all Federal and non-Federal costs necessary for establishing, maintaining and operating the project.	Benefits, consisting of increa in gross incomes on lands on which program measures are in stalled, increases in gross incomes less increased costs production on other lands, ar reductions in costs and losse on all lands, are compared wi project costs which include both public and private exper itures for the program instal lation and operation.
2. Period of analysis used in estimating benefits and costs.	Estimated economically useful life, limited to maximum of 50 years in all but exceptional cases.	A perpetual life basis is assumed.
3. Time basis used for expressing monetary amounts of benefits and costs.	All benefits and costs are converted to equivalent average annual amounts for the period of analysis.	Same as indicated in column 2.
BENEFITS		
4. Price level used in calculating benefits.	Price level prevailing at time of analysis.	Do.
5. Interest rates used for conversion of nonuniform benefits to an equivalent average annual benefit.	Average rate of interest payable on money borrowed for long-term private investments in the locality concerned. Rates from 4 to 5 per cent are generally used.	2 per cent except as shown for item 8 below.
6. Method of measuring benefits from preventing flood damage.	Benefits are measured as the amounts of reduction of flood damage, computed on the basis of damage-frequency relations, with damages measured as follows: Damage to land and other property measured by the cost of restoration is not possible, damage is measured as reduction in value of the property; damage to agricultural crops measured by market value of crop lost adjusted for any production costs not incurred and replanting possibilities; and damage due to interruption of business, industry, commerce, etc., measured by net loss of income or added costs of operation to the extent such losses or costs cannot be avoided.	Same general basis as describe in column 2 except that damage due to interruption of business, etc., is usually not measured.
7. Method of measuring benefits	Benefit computed as the increase	For lands on which the program

measurement of tangible benefits and costs[a]

rtment of Agriculture[c] (3)	Bureau of Reclamation[d] (4)	Federal Power Commission[e] (5)
consisting of increases incomes on lands on ogram measures are in- increases in gross less increased costs of on on other lands, and ns in costs and losses ands, are compared with costs which include lic and private expend- or the program instal- nd operation.	Irrigation benefits as measured by the effects of the project on contribution to national income, plus other types of benefits as measured principally by the value of services rendered, are compared with Federal (project) costs for installation and operation of the project.	Hydroelectric power benefits, including the value of capacity and energy at the project and the improvement in downstream power, plus nonpower benefits as estimated by the agency responsible for the project, all reduced by any nonproject costs required for their realization, are compared with the Federal cost of establishing, maintaining, and operating the project.
al life basis is	Estimated economically useful life of principal project features or 100 years, whichever is less (see items 25 and 26 for treatment of salvage values).	Estimated economically useful life, limited to maximum of 50 years.
ndicated in column 2.	Same as indicated in column 2.	Same as indicated in column 2.
	Irrigation.-Estimated average prices during project life--currently, 1939-44 prices are used. Power.-Expected average power rates during project life. Recreation.-Expected average prices during project life. Fish and wildlife.-Sportsman's expenditures based on 1939-44 prices. Commercial fur and fish prices based on local data within 10-year period prior to period of analysis.	Do.
t except as shown for elow.	2½ per cent.	Power benefits are usually measured directly on average annual basis and no conversion is involved.
ral basis as described n 2 except that ue to interruption of , etc., is usually ured.	Estimates obtained from Corps of Engineers or, when necessary, independent estimates made by similar methods. In either case, adjustments are made to give a price level basis same as for irrigation.	Estimates obtained from Corps of Engineers or, when necessary, independent estimates made by similar methods.
on which the program	Contributions to national in-	Estimates obtained from agency

5. Interest rates used for conversion of nonuniform benefits to an equivalent average annual benefit.	Average rate of interest payable on money borrowed for long-term private investments in the locality concerned. Rates from 4 to 5 per cent are generally used.	2 per cent except as shown item 8 below.
6. Method of measuring benefits from preventing flood damage.	Benefits are measured as the amounts of reduction of flood damage, computed on the basis of damage-frequency relations, with damages measured as follows: Damage to land and other property measured by the cost of restoration is not possible, damage is measured as reduction in value of the property; damage to agricultural crops measured by market value of crop lost adjusted for any production costs not incurred and replanting possibilities; and damage due to interruption of business, industry, commerce, etc., measured by net loss of income or added costs of operation to the extent such losses or costs cannot be avoided.	Same general basis as desc in column 2 except that damage due to interruptio business, etc., is usuall not measured.
7. Method of measuring benefits from increase in value of agricultural production. (Includes such benefits as increased crops resulting from irrigation and the improved farm practices involved in watershed treatment programs and the increased crops possible on land that is drained or protected from floods.).	Benefit computed as the increase in net farm income. In general, this is the increase in gross farm income minus the increase in cost of production. Effects of increased agricultural production on incomes other than at the farm are usually not measured.	For lands on which the pro measures are installed, benefits are measured as increase in gross farm in come with increases in production costs accounte for as a part of program costs. For land down stream (land other than that on which project measures are installed) t benefit is taken as the i crease in net farm income. In general, this is the increase in gross farm inc minus the increase in cos of production. Effects o increased agricultural pr duction other than at the farm are usually not measured.
8. Method for measuring benefits from increased or higher utilization of nonagricultural property.	Any benefits over and above those measured under other items such as 6 and 7 above are measured in terms of increases in earnings expected under average future conditions due to the changes in use made practicable by the project. The annual increases in earnings are determined by applying the current average rate of return associated with the activity concerned to the increase in in capital value, except in cases where the increase in earning power can be determined.	Any benefits over and above measured under other items as 6 and 7 above are measu terms of increases in pro values above the capitali value of all damage reduc Estimates of increases in property values are obtai either from studies of va in comparable areas or by capitalizing the anticipa increase in annual land i These benefits are convert to an average annual basi use of a selected rate of usually between $4\frac{1}{2}$ and $6\frac{1}{2}$

	fish prices based on local data within 10-year period prior to period of analysis.	
cent except as shown for 8 below.	2½ per cent.	Power benefits are usually measured directly on average annual basis and no conversion is involved.
eneral basis as described lumn 2 except that e due to interruption of ess, etc., is usually easured.	Estimates obtained from Corps of Engineers or, when necessary, independent estimates made by similar methods. In either case, adjustments are made to give a price level basis same as for irrigation.	Estimates obtained from Corps of Engineers or, when necessary, independent estimates made by similar methods.
nds on which the program res are installed, its are measured as the ase in gross farm in- with increases in ction costs accounted s a part of program . For land down- n (land other than on which project res are installed) the it is taken as the in- e in net farm income. neral, this is the ase in gross farm income the increase in cost oduction. Effects of ased agricultural pro- on other than at the are usually not red.	Contributions to national income consisting of: Effects at the farm (termed "direct benefits").-(a) Increase in difference between gross farm income (farm receipts plus farm privileges) and all farm expenses. (b) Increase in wages paid hired farm laborers. (c) Increase in interest payment on farmers' borrowed capital. Effects beyond the farm (termed "indirect benefits") -(a) Share of added income resulting from additional volume of agricultural products flowing through industry and trade. (b) Share of added income from increased purchases of goods and services in the project area.	Estimates obtained from agency responsible for the project concerned.
nefits over and above those red under other items such and 7 above are measured in of increases in property s above the capitalized of all damage reductions. ates of increases in rty values are obtained from studies of values mparable areas or by alizing the anticipated ase in annual land income. benefits are converted average annual basis by f a selected rate of return; ly between 4½ and 6½ per cent	Benefits of use of land for residential purposes are measured by converting the estimated future increase in market value of such lands to an equivalent average annual value. The standard interest rate of 2½ per cent is used.	Estimates obtained from agencies responsible for project.

Table 2. (Continued)

Practices to be compared (1)	Corps of Engineers[b] (2)	Department of Agriculture[c] (3)
BENEFITS--continued		
	directly.	
9. Method of measuring benefits from increasing hydroelectric power production.	Amount of power computed on the same basis used by the Federal Power Commission. Benefit is computed by applying to the above amounts unit values for capacity and energy obtained from the Federal Power Commission.	Usually not evaluated in monetary terms.
10. Method for measuring navigation benefits.	Savings to shippers measured as the difference between cost of transportation by cheapest available alternative and cost of transportation by waterway; savings in water-carrier time and operating costs on an improved waterway when it will supersede an existing waterway; estimated recreational value of harbors and waterways to small boat traffic. More extended often or secondary effects such as stimulation of business activity are not usually measured.	Do.
11. Method for measuring domestic and industrial water supply benefits.	Measured by the cost of providing the most economical alternative means of obtaining the needed water. Where there is no other practical alternative means, the benefit is measured by determining the value of the additional water to the consumer, sometimes in terms of ability to pay.	Reduction in water supply treatment costs (usually computed as a sedimentation control benefit).
12. Method for measuring sedimentation control benefits.	Value of damage prevented (similar to flood control), reduction in cost of services provided, or value of avoidance of impairment of a useful function.	Value of damage prevented, reduction in cost or increase in value of services provided, or value of extended life of facilities.
13. Method for measuring benefits from pollution abatement.	Measured by the cost of providing the most economical alternative methods of waste treatment or disposal, or reduction in maintenance and operating costs where alternative methods of pollution abatement are not	Usually not evaluated in monetary terms.

artment of Agriculture[c]	Bureau of Reclamation[d]	Federal Power Commission[e]
(3)	(4)	(5)
t evaluated in terms.	Estimated gross revenue to the project from energy sales with adjustment for any gains or losses at downstream plants is measured and termed the "direct benefit." Additional effects of the production of power, termed "indirect benefits" are measured as follows: (a) Share of returns to distributors of project power. (b) Saving to consumers from lower power rates. (c) Benefit attributable to project power in the final production of goods and services.	Hydroelectric power value consisting of: Value at the bus bar of the project for dependable and usable capacity during critical stream-flow period and for usable energy from average stream flow based upon cost of capacity and energy from most economical source, other than hydro, of providing power, usually privately financed, modern, efficient, steam-electric power. Improvements in downstream power values attributable to the project, reduced by any costs incurred by the downstream beneficiaries in order to realize the improved power values.
	Estimates obtained from Corps of Engineers or, when necessary, independent estimates made by similar methods. In either case, adjustments are made to give a price level basis same as for irrigation.	Estimates obtained from Corps of Engineers or, when necessary, independent estimates made by similar methods.
in water supply treat-s (usually computed as rtation control benefit).	Measured by the cost of providing the most economical alternative means of obtaining the needed water. Where there is no other practical alternative means, the benefit is measured by determining the amount of project revenues expected from this source. Firefighting benefits may be found by either determining the probability of fires with their resulting damages, or by calculating the change in rate of fire insurance, as done by the National Board of Fire Underwriters.	Estimates obtained from agency responsible for project or, when necessary, independent estimates made by similar methods.
lamage prevented, re-ln cost or increase of services provided, of extended life of es.	Same practice as that described in column 3.	Estimates obtained from agencies responsible for project.
ot evaluated in mone-ns.	Same practice as that described in column 2.	Estimates obtained from agency responsible for project, or, when necessary, independent estimates made by similar methods.

	ten or secondary effects such as stimulation of business activity are not usually measured.	
11. Method for measuring domestic and industrial water supply benefits.	Measured by the cost of providing the most economical alternative means of obtaining the needed water. Where there is no other practical alternative means, the benefit is measured by determining the value of the additional water to the consumer, sometimes in terms of ability to pay.	Reduction in water supply treatment costs (usually computed a a sedimentation control benefi
12. Method for measuring sedimentation control benefits.	Value of damage prevented (similar to flood control), reduction in cost of services provided, or value of avoidance of impairment of a useful function.	Value of damage prevented, reduction in cost or increase in value of services provided, or value of extended life of facilities.
13. Method for measuring benefits from pollution abatement.	Measured by the cost of providing the most economical alternative methods of waste treatment or disposal, or reduction in maintenance and operating costs where alternative methods of pollution abatement are not economical.	Usually not evaluated in monetary terms.
14. Method for measuring salinity control benefits.	Value of damage prevented, increased use made possible, or maintenance costs avoided--determined in manner similar to that for flood control (item 6 above).	Do.
15. Method for measuring recreational benefits.	Except as covered in item 10, usually not included in benefit estimates but in order to permit consideration outside of monetary benefit-cost comparison, benefits are evaluated in general monetary and nonmonetary terms after consultation with National Park Service.	Do.
16. Method for measuring fish and wildlife benefits.	Standard procedures for estimating fish and wildlife benefits have not been adopted. Often not included in monetary benefit-cost comparison, but when included both qualitative and quantitative data are based upon estimates made by the U. S. Fish and Wildlife Service.	Do.
17. Method for measuring benefits from increased employment.	Not measured because during normal times increased employment is assumed to be essentially a diversion from other equally profitable sources of employment. During periods of depression the possibility of increased employment is considered to be a factor which is outside the project economics but which may be given consideration in selecting the project for construction.	Not measured for the same reasc listed in column 2.

ion in water supply treat- costs (usually computed as limentation control benefit).	Measured by the cost of providing the most economical alternative means of obtaining the needed water. Where there is no other practical alternative means, the benefit is measured by determining the amount of project revenues expected from this source. Firefighting benefits may be found by either determining the probability of fires with their resulting damages, or by calculating the change in rate of fire insurance, as done by the National Board of Fire Underwriters.	Estimates obtained from agency responsible for project or, when necessary, independent estimates made by similar methods.
of damage prevented, re- ion in cost or increase alue of services provided, alue of extended life of ilities.	Same practice as that described in column 3.	Estimates obtained from agencies responsible for project.
ly not evaluated in mone- terms.	Same practice as that described in column 2.	Estimates obtained from agency responsible for project, or, when necessary, independent estimates made by similar methods.
	Same practice as that described for Corps of Engineers.	Estimates obtained from agencies responsible for project.
	Recreational benefits estimated by the National Park Service based on expected expenditures by persons visiting the area plus general benefits to surrounding areas (consideration is currently being given to revision of this practice).	Do.
	Increased value of annual yields estimated by the Fish and Wildlife Service based on expenditures of sportsmen for fishing and hunting and on gross market value of fish and fur taken for commercial purposes.	Do.
easured for the same reasons ed in column 2.	Part of labor's share of added income measured as part of the benefits from agricultural production and from power. (See items 7 and 9).	Recognized but not measured or evaluated.

Table 2. (Continued)

Practices to be compared (1)	Corps of Engineers[b] (2)	Department of Agriculture[c] (3)
BENEFITS--continued		
18. Method for measuring benefits from increased use of capital.	Not measured because it is assumed that other equally profitable methods of using capital could be employed and that, therefore, there is no increased return from the use of capital on the project.	Do.
COSTS		
General cost practices		
19. Price level used in calculating costs.	Price level prevailing at the time of the analysis.	Same as indicated in column 2.
20. Interest rate used for convertingnonuniform costs to an equivalent average annual cost.	3 per cent for Federal and 3½ per cent for non-Federal cost.	2 per cent for all costs.
Investment costs		
21. Types of costs included in initial investment costs. (Differences in measurement practices for similar types are described in items 22 to 26 below.)	All costs, subsequent to authorization of the project by Congress, for labor, materials, and equipment necessary to design and construct a project; lands and rights-of-way for construction and operation; damage compensations; structural and utility relocations, remedial measures, legal expenses, overhead costs, and all other costs incurred in establishing the project, including interest during construction and allowances for contingencies and for salvage value of land.	All Federal and private costs, subsequent to authorization of the project by Congress, or establishing program measures including labor, materials, equipment, lands and rights-of-way, engineering plans and designs, technical assistance and supervision, and allowances for contingencies and for guidance and assistance in relocating displaced families.
22. Allowance made for interest during construction.	Included for ½ of the construction period at 3 per cent for Federal investment and 3½ per cent for non-Federal investment.	Not included because benefits either begin when expenditures are made or are discounted to the time of the expenditures.
23. Allowance made in estimates for contingencies.	Included in various portions of the estimate in amounts appropriate to the degree of refinement and accuracy inherent in the estimates of physical quantities and unit price data.	Same practice as that described in column 2.
24. Allowance made for consequential damages.	Not included in monetary estimate of cost.	Allowance is made for the cost of financial and guidance assistanc expected to be provided to persons displaced by land acquisition.
25. Method of allowing for salvage value of land.	Investment to be amortized is reduced by the estimated future value of land at end of a period	Not applicable because of assumption of perpetual life for the program.

rtment of Agriculture[c] (3)	Bureau of Reclamation[d] (4)	Federal Power Commission[e] (5)
	Part of capital's share of added income measured as part of the benefits from agricultural production and from power. (See items 7 and 9).	Not measured or evaluated.
dicated in column 2.	Prices prevailing at the time of analysis for construction costs. Expected future prices for operation and maintenance (currently, future prices for irrigation based on 1939-44 average and on power, based on special investigations.).	Same as indicated in column 2.
for all costs.	2½ per cent for Federal costs. Non-Federal costs are taken into account under Benefits. (See item 7.)	2½ per cent for all costs.
l and private costs, t to authorization of ct by Congress, or ing program measures labor, materials, , lands and rights- ngineering plans and technical assistance vision, and s for contingencies uidance and assistance ting displaced	Same types included as those indicated in column 2 except that an allowance is made for salvage as determined by remaining use value of major structures.	All costs for labor, materials, equipment, lands, rights-of-way, damage compensations, structural and utility relocations and remedial measures required to establish the project, plus 25 to 35 per cent of the total amount of such costs to cover such additional costs as engineering, inspection, legal expense, administrative and miscellaneous general expense, interest during construction, and allowance for contingencies.
ed because benefits gin when expenditures or are discounted to of the expenditures.	Included as a percentage of total construction cost as estimated to fit the conditions for each project. Included for one-half of construction period as 2½ per cent.	Same practice as that described in second sentence column 4.
ice as that described 2.	Included as a percentage of total construction cost as estimated to fit the conditions for each project.	Included in total investment cost. (See item 21.)
is made for the cost of and guidance assistance to be provided to displaced by land on.	Not included in monetary estimate of costs.	Not included in monetary estimate of cost.
able because of assump- erpetual life for the	Initial investment reduced by present worth of estimated future value of land at end	No allowance made for salvage values of land.

supervision, and owances for contingencies for guidance and assistance relocating displaced ilies.		per cent of the total amount of such costs to cover such additional costs as engineering, inspection, legal expense, administrative and miscellaneous general expense, interest during construction, and allowance for contingencies.
included because benefits her begin when expenditures made or are discounted to time of the expenditures.	Included as a percentage of total construction cost as estimated to fit the conditions for each project. Included for one-half of construction period as 2½ per cent.	Same practice as that described in second sentence column 4.
practice as that described column 2.	Included as a percentage of total construction cost as estimated to fit the conditions for each project.	Included in total investment cost. (See item 21.)
vance is made for the cost of ancial and guidance assistance ected to be provided to sons displaced by land uisition.	Not included in monetary estimate of costs.	Not included in monetary estimate of cost.
applicable because of assump- n of perpetual life for the gram.	Initial investment reduced by present worth of estimated future value of land at end of period of analysis (net result same as Corps of Engineers' method).	No allowance made for salvage values of land.
applicable because of the as- ption of perpetual life for program.	Initial investment reduced by present worth of remaining use value, at end of period of analysis, of major structures on straight line depreciation basis over the life of the structure, not to exceed 150 years. (See item 28.)	No allowance made for salvage values of major structures.
rest on initial investment without any deduction for rage value of land or major uctures is included in annual in perpetuity at an erest rate of 2 per cent.	Interest is included in the annual cost over the period of analysis on the initial investment cost reduced by present worth of salvage or remaining use value of land and major structures at an interest rate of 2½ per cent.	Same practice as that described in column 2 except that interest rate of 2½ per cent is used.
ization is not included be- se of the assumption of petual life.	An amount is included in the annual cost over the period of analysis to amortize the initial investment cost reduced by the present worth of the salvage values for land and for major structures (see items 25 and 26) using interest rate of 2½ per cent.	An amount of 1.03 per cent of total investment cost is included in annual fixed charges to amortize this investment cost in full over the period of analysis, using an interest rate of 2½ per cent.
uded as part of maintenance s and computed by ding the initial cost by life of the item.	Same as indicated in column 2 except that the present worth of the replacement costs are reduced by the present worth	Average annual replacement cost usually estimated as about 0.60 per cent of total investment cost on the basis that this

Table 2. (Continued)

Practices to be compared (1)	Corps of Engineers[b] (2)	Department of Agriculture[c] (3)
COSTS--continued		
Annual costs--continued		
	to present worth values upon which interest and amortization are charged over the full period of analysis. No salvage credit is taken for the remaining value of the last major replacement the life of which may extend beyond the life of the project.	
30. Allowance made for insurance costs.	Not included.	Not included.
31. Allowance made in lieu of taxes.	Loss of taxes to local taxing agencies as a result of transfer of lands and property to Federal ownership is included as an annual charge against the project over the period of analysis. This charge may be offset by increased revenue to local taxing agencies from reservoir land rentals in accordance with sec. 7 of the 1941 Flood Control Act and subsequent Acts.	No allowance made because it is assumed that increases and decreases in taxes offset each other.[f]
32. Allowance made for operation and maintenance costs.	Includes all costs, other than those accounted for in the initial investment, which are expected to be incurred, during the period of analysis in order to maintain and operate it for the intended purposes.	All costs, Federal or private, necessary to operate the programs and to maintain the program investments for perpetual life including increases in production costs on lands on which project measures are installed.

[a]Source: 123, pp. 74-81.
83, p. 2.6.2

[b]Practice on navigation, flood control, and multiple-purpose projects.

[c]Practice on watershed treatment programs.

[d]Practice on irrigation and multiple-purpose projects.

[e]Practice on Federal multiple-purpose projects involving power development.

[f]"On March 12, 1954 the Departments of Army and Interior and the Federal Power Commission adopted economically feasible when the value of power would at least equal the project costs allocated to powe federal development of the power rather than the most likely alternative development. ... This procedu proposed federal project and interest rates for the alternative project such as it would have to pay."

Department of Agriculture[c] (3)	Bureau of Reclamation[d] (4)	Federal Power Commission[e] (5)
	of any remaining use value of replaceable items on a straight line depreciation basis where the life of the replaceable items extends beyond the life of the project, but no such remaining use values are considered beyond 150 years.	allowance is approximately equivalent to providing annually during the entire period of analysis for a charge for each replaceable item which, on a 2.5 per cent sinking fund basis over the life of the item, will provide for the cost of replacing the item.
ncluded.	Not included.	Included in annual fixed charges over the period of analysis as 0.12 per cent of total investment cost.
lowance made because it is med that increases and eases in taxes offset other.[f]	Same practice as that described in column 3.[f]	An amount averaging about 1.40 per cent of total investment cost is included in annual fixed charge over the period of analysis as an allowance in lieu of state and local taxes that would be paid if the project were privately owned.[f]
osts, Federal or private, ssary to operate the rams and to maintain the ram investments for per- al life including in- ses in production costs ands on which project ures are installed.	Same practice as that described in column 2.	Annual operating expense includes all costs for labor and materials for maintenance and operation of hydroelectric power development as well as for administrative and miscellaneous general expense over the period of analysis.

pment.

ral Power Commission adopted an agreement providing that hydroelectric projects would be considered ject costs allocated to power, plus the amount of taxes which would be foregone as a result of evelopment. ... This procedure contemplated the use of long-term federal interest rates for the ch as it would have to pay." (130, p. 3)

DISCUSSION, IF THE RATIO IS TO SERVE BOTH AS A CRITERION FOR PROJECT JUSTIFICATION AND AS A MEASURE OF RELATIVE MERIT OF PROPOSED PROJECTS, THE RATIO BECOMES THE CENTER OF CONFLICTING PURPOSES. IN ORDER TO SECURE JUSTIFICATION OF A PROJECT, LOOSE STANDARDS ARE OFTEN ENCOURAGED TO BOOST THE PROJECT PAST THE SHIBBOLETH OF A RATIO OF 1.0 WHILE ANY RATIO WHICH IS USED AS A MEASURE OF RELATIVE MERIT REQUIRES CONSISTENCY OF STANDARDS AND EXACT ANALYSIS.[1]

IN SPITE OF THESE PROBLEMS, THE BENEFIT-COST RATIO STILL OFFERS THE OPPORTUNITY TO PLACE NONPROFIT EXPENDITURE DECISIONS UPON A FIRMER ANALYTICAL BASIS. THE RATIO IS GENERALLY USED AS AN AID IN DECISION MAKING AT THE PRESENT TIME. A PROJECT IS DEEMED TO BE JUSTIFIED ECONOMICALLY IF ITS BENEFIT-COST RATIO EXCEEDS UNITY, AND THE GREATER THE RATIO, THE HIGHER THE PRIORITY OF THE PROJECT. THUS, THE RATIO IS TAKEN TO INDICATE THE NUMBER OF FEASIBLE PROJECTS PROPOSED AND THE ORDER IN WHICH THE PROJECTS SHOULD BE UNDERTAKEN, INFORMATION WHICH HAS A STRONG RELATIONSHIP TO AN AGENCY'S FUTURE BUDGET.

NATURALLY, THE BENEFIT-COST RATIO IS NOT THE ONLY PIECE OF EVIDENCE WHICH IS RELEVANT TO A MEASURE OF PUBLIC WORTH OF A WATER RESOURCE EXPENDITURE. ANY RIGID FIGURE ESTABLISHED AS A MINIMUM FOR PROJECT FEASIBILITY WOULD PLACE UNWARRANTED EMPHASIS ON THE ACCURACY OF PREDICTIONS AND THE VALIDITY OF

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[1]THIS POINT IS MADE BY ECKSTEIN (15, P. 48).

SUCH AN INDEX. HOWEVER, FOR THE PURPOSE OF THE REMAINDER OF THIS STUDY, THE APPLICABILITY AND VALIDITY OF THE BENEFIT-COST RATIO WILL BE ACCEPTED. THIS STUDY PURPORTS TO INVESTIGATE THE AFFECT OF ESTIMATION UNCERTAINTY UPON THE BENEFIT-COST RATIO RATHER THAN THE VALIDITY OF THIS RATIO AS A DECISION CRITERION.

DETERMINATION OF BENEFITS AND COSTS

THE BENEFITS AND COSTS ASSOCIATED WITH NONPROFIT CAPITAL EXPENDITURE PROPOSALS OCCUR IN DIVERSE PHYSICAL FORMS, AT DIFFERENT POINTS IN TIME, AND OVER VARYING PERIODS OF TIME. THUS, IN ORDER TO COMPARE THE BENEFITS DERIVED FROM A PROJECT WITH ITS CORRESPONDING COSTS, SOME COMMON BASIS OF MEASUREMENT MUST BE ESTABLISHED.

> SYSTEMATIC TREATMENT OF ALL COSTS AND BENEFITS IN AN ECONOMIC ANALYSIS IS ESSENTIAL FOR CONSISTENCY AND COMPARABILITY OF RESULTS. (121, P. 7)

THE BENEFITS DERIVED FROM A PROJECT ARE USUALLY THE GOODS AND SERVICES WHICH THE PROJECT YIELDS WHILE THE PROJECT COSTS MAY BE CONSIDERED A LOSS OR NEGATIVE ITEM IN TERMS OF GOODS AND SERVICES. SINCE, PRESUMABLY, THE PUBLIC IS INTERESTED IN ASCERTAINING THE REAL WORTH OF GOODS AND SERVICES AND THE REAL COST OF A PROJECT, A DETERMINATION OF THE BENEFITS AND COSTS IS MADE WHICH OFTEN SEEMS AT ODDS WITH THIS STATED OBJECTIVE; THAT IS, THE ANALYSIS OF THE PROJECT IS MADE IN TERMS OF DOLLAR VALUES.

TWO REASONS FOR MEASURING BENEFITS AND COSTS IN DOLLARS ARE AT ONCE EVIDENT. FIRST, WHENEVER SETS OF DISSIMILAR

ITEMS MUST BE EXPRESSED AS A COMBINED TOTAL, THE ADDITION OF QUANTITIES OF GOODS STATED IN PHYSICAL TERMS IS MEANINGLESS. THUS, THE DOLLAR VALUES SERVE AS A CONVENIENT COUNTING DEVICE. SECOND, DOLLAR VALUES REPRESENT A MEANS OF EXPRESSING THE WORTH OF SOMETHING IN A MANNER WHICH IS RECOGNIZABLE TO MOST PEOPLE. IN THIS WAY THE TOTAL PRODUCTION OF GOODS AND SERVICES RESULTING FROM A CAPITAL EXPENDITURE WOULD HAVE A VALUE TO SOCIETY WHICH IS DESCRIBED BY THE DOLLAR VALUE ASSIGNED TO THOSE GOODS AND SERVICES. THUS, THE UNIT OF THE DOLLAR EMBRACES BOTH THE FUNCTION OF A COUNTING DEVICE AND THE FUNCTION OF A MEASURE OF UTILITY, OR VALUE, WHICH THE PUBLIC DERIVES FROM THE GOODS AND SERVICES PRODUCED BY A PROJECT. THIS DUAL FUNCTION OF THE MONETARY UNIT IN TRANSLATING PROJECT BENEFITS AND COSTS TO A COMMON, COMPARATIVE BASIS REQUIRES A CONSISTENT SET OF STANDARDS DEFINING EXACTLY WHAT CONSTITUTES A BENEFIT OR A COST.

WHEN BENEFITS AND COSTS OF A PROJECT ARE EVALUATED, A COMPARISON IS MADE BETWEEN TWO SITUATIONS, THE DEVELOPMENT OF THE ECONOMY WHICH WOULD OCCUR WITH THE PROJECT AND THE DEVELOPMENT OF THE ECONOMY WHICH WOULD OCCUR WITHOUT THE PROJECT. THIS WITH AND WITHOUT PRINCIPLE AVOIDS ERRONEOUS CONCLUSIONS WHICH MIGHT RESULT FROM A BEFORE AND AFTER ANALYSIS. THE OBJECT OF ESTABLISHING THE HYPOTHETICAL SITUATION NECESSARY FOR A WITH AND WITHOUT ANALYSIS IS TO IDENTIFY CHANGES WHICH WOULD OCCUR AS A RESULT OF THE PROJECT. THIS WOULD REDUCE THE POSSIBILITY OF ATTRIBUTING EFFECTS TO

THE PROJECT WHICH WOULD OCCUR WITH THE NATURAL PASSAGE OF TIME OR WHICH WOULD OCCUR AS THE RESULT OF OTHER EXTERNAL CAUSES.

IN THE REPORT OF THE SUBCOMMITTEE ON BENEFITS AND COSTS (123) AND MORE OR LESS IN AGENCY PRACTICE, THE BENEFITS ACCRUING TO AN INDIVIDUAL FROM A PROJECT HAVE BEEN DEFINED AS THAT AMOUNT OF MONEY WHICH THE INDIVIDUAL WOULD BE WILLING TO PAY IF HE WERE GIVEN THE MARKET CHOICE OF PURCHASE, A CONCEPT WHICH CORRESPONDS TO THE CLASSICAL CONSUMPTION THEORY OF ECONOMICS. IN ORDER TO FORM AN AGGREGATE PICTURE OF THE BENEFITS ACCRUING TO ALL INDIVIDUALS AFFECTED BY A PROJECT, THE SIMPLEST ASSUMPTION HAS GENERALLY BEEN ADHERED TO, THAT OF ADDING THE BENEFITS ACCRUING TO ALL PEOPLE, GIVING EACH INDIVIDUAL AN EQUAL WEIGHTING FACTOR. WHILE THIS METHOD HAS THE ADVANTAGE OF COMPUTATIONAL SIMPLICITY, COMPLEX VALUE JUDGMENTS CONCERNING IMPERSONAL COMPARISONS UNDERLIE THIS ASSUMPTION.

IT IS INTERESTING TO NOTE, HOWEVER, THAT EVEN A DETAILED ANALYSIS OF COSTS AND BENEFITS USING A HYPOTHETICAL WITH AND WITHOUT SITUATION WOULD PROBABLY NOT MEET THE STATUTORY REQUIREMENTS IMPOSED UPON THE CORPS OF ENGINEERS BY THE FLOOD CONTROL ACT OF 1936, THAT IS, MEASURING ALL BENEFITS AND COSTS TO WHOMSOEVER THEY ACCRUE. SUCH A MEASUREMENT WOULD PRESENT CONCEPTUAL DIFFICULTIES WHICH WOULD NECESSITATE ASSUMPTIONS BEYOND THE BOUNDS OF EXISTING STATUTES AND ESTABLISHED STANDARDS. IN ADDITION, PRECISE MEASUREMENTS OF THIS NATURE

WOULD BE BEYOND PRESENT TECHNOLOGY AND WOULD REQUIRE A GREATER ACCURACY THAN IS AVAILABLE IN ECONOMIC DATA PRESENTLY REPORTED.[1]

MENTION OF SOME OF THE DIFFICULTIES ASSOCIATED WITH THE ESTABLISHMENT OF DEFINED STANDARDS OF BENEFITS AND COSTS WAS MADE ONLY TO CALL ATTENTION TO THE COMPLEXITY OF THE PROBLEM SINCE THE EXISTING DEFINITIONS FURNISH USEFUL INFORMATION IN THEIR PRESENT STATE OF REFINEMENT. FOR THE PURPOSES OF ECONOMIC EVALUATION FROM A NATIONAL POINT OF VIEW, THE PROJECT BENEFITS ARE THE SUM OF THE PRIMARY BENEFITS AND THE ATTRIBUTABLE SECONDARY BENEFITS. THE PRIMARY BENEFITS ATTRIBUTABLE TO A PROJECT ARE REPRESENTED BY THE MARKET VALUE OF GOODS AND SERVICES RESULTING DIRECTLY FROM THE PROJECT, LESS ALL OF THE ASSOCIATED COSTS INCURRED IN THEIR REALIZATION (123, P. 8).

> ... [T]HE SECONDARY BENEFITS PROPERLY ATTRIBUTABLE TO A PROJECT FOR PURPOSES OF ECONOMIC JUSTIFICATION ARE [OVER AND ABOVE THE VALUE OF THE PRIMARY BENEFITS AND ARE] THE EXCESS OF SECONDARY BENEFICIAL EFFECTS OVER THE SUM OF: (A) THE COSTS INCURRED IN SECONDARY ACTIVITIES; AND (B) THE NET SECONDARY BENEFITS THAT WOULD HAVE BEEN EXPECTED FROM OTHER USES OF PROJECT REQUIRED RESOURCES. THESE CONTRAST WITH THE OVERALL SECONDARY BENEFITS WHICH, FROM A LOCAL OR REGIONAL VIEWPOINT ARE THE VALUES ADDED IN SECONDARY ACTIVITIES. THE OVERALL SECONDARY BENEFITS MAY BE APPROPRIATE... IN ILLUSTRATING THE SIGNIFICANCE OF PROJECTS FROM A LOCAL OR REGIONAL POINT OF VIEW. (123, P. 8)

WHILE FEDERAL AGENCIES CONCUR WITH THESE DEFINITIONS IN BASIC PRINCIPLE, AS MENTIONED PREVIOUSLY, THE PROCEDURES

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[1]THIS POINT IS DISCUSSED BY MORGENSTERN (48).

FOLLOWED IN PERFORMING A BENEFIT-COST ANALYSIS VARY AMONG THE AGENCIES. THESE VARIATIONS WERE SHOWN IN THE COMPARATIVE TABLE 2, PAGE 15. THE SUBCOMMITTEE TO STUDY CIVIL WORKS OF THE COMMITTEE ON PUBLIC WORKS POINTED OUT THAT THE DIFFERENCES IN THESE PROCEDURES WOULD RESULT IN THE SITUATION WHERE IF THE BENEFIT-COST RATIO FOUND BY THE BUREAU OF RECLAMATION WERE 1:1, THE RATIO FOUND BY THE CORPS OF ENGINEERS WOULD BE 0.75:1 AND THE RATIO FOUND BY THE DEPARTMENT OF AGRICULTURE WOULD BE 1.04:1 (112, P. 9).

ADDITIONAL INFORMATION ON POSSIBLE IMPROVEMENTS TO THE DEFINITIONS OF BENEFIT AND COST COMPONENTS, ON THE USE OF GROSS OR NET VALUES OF BENEFITS AND COSTS IN THE BENEFIT-COST RATIO, AND ON THE VALIDITY OF THE BENEFIT-COST RATIO AS A DECISION CRITERION MAY BE FOUND IN OTHER WORKS (7, 10, 14, 15, 22, 23, 24, 28, 36, 38, 44, 45, 55, 56, 62, 63, 65, 123, 124, 127, 128, 130, 131). THIS SIZEABLE BODY OF KNOWLEDGE DISCUSSES THE ESTIMATES MADE TO JUSTIFY FEDERAL CAPITAL EXPENDITURES; YET, ONLY McKEAN (44) MENTIONS THE EFFECT OF UNCERTAINTY UPON DEVIATIONS ABOUT THE EXPECTED VALUE OF THESE ESTIMATES, UNCERTAINTY WHICH IS INHERENT TO ALL ESTIMATED COMPONENTS, EITHER NOW IN USE OR PROPOSED. THUS, WHILE UNCERTAINTY OBVIOUSLY EXISTS, AS EVIDENCED FROM THE CONTROVERSY OVER PAST EXAMPLES OF MISESTIMATION, AN ATTEMPT IS USUALLY MADE TO LUMP ALL UNCERTAINTY INTO ONE, ALL-ENCOMPASSING ADJUSTMENT FACTOR.

SINCE UNCERTAINTY HAS SUCH A PROFOUND EFFECT UPON THE

ESTIMATION PROCESS AND THE STATEMENT OF FEASIBILITY RESULTING FROM THESE ESTIMATES, THE REMAINDER OF THIS STUDY WILL BE DEVOTED TO A DISCUSSION OF THE UNCERTAINTIES PRESENT IN ESTIMATES OF EXPECTED VALUES OF BENEFITS AND COSTS. A POSSIBLE METHOD OF PROVIDING AN IMPROVED RECOGNITION OF DEVIATIONS IN ESTIMATES OF EXPECTED VALUES OF BENEFITS AND COSTS WILL ALSO BE DISCUSSED IN LIGHT OF THE EFFECTS OF THESE DEVIATIONS UPON THE BENEFIT-COST RATIO. THUS, THIS INVESTIGATION IS AN ATTEMPT TO IMPROVE UPON THE CRITERION NOW USED AS A DECISION AID RATHER THAN A DISCUSSION OF THE CRITERIA THEMSELVES.

ESTIMATION UNCERTAINTY

> ... [O]WING TO OUR INABILITY TO DISTINGUISH TRUE FROM FALSE, WE ARE FORCED TO REGARD THE DOUBTFUL AS CERTAIN; FOR IN THOSE MATTERS ANY HOPE OF AUGMENTING OUR KNOWLEDGE IS EXCEEDED BY THE RISK OF DIMINISHING IT. THUS IN ACCORDANCE WITH THE ABOVE MAXIM WE REJECT ALL SUCH MERELY PROBABLE KNOWLEDGE AND MAKE IT A RULE TO TRUST ONLY WHAT IS COMPLETELY KNOWN AND INCAPABLE OF BEING DOUBTED. (13, P. 2)

UNFORTUNATELY, ONE IS UNABLE TO DISREGARD ALL THAT WHICH POSSESSES AN AURA OF UNCERTAINTY, FOR TO DO SO WOULD REQUIRE ISOLATION FROM LIFE ITSELF. THUS, IF ONE, RATHER THAN REJECTING THE UNCERTAIN, TRIES TO EXPAND ONE'S KNOWLEDGE OF THE ENVIRONMENT SURROUNDING THE UNCERTAINTY, ONE GAINS AN EXPANDING KNOWLEDGE OF THE BEHAVIORIAL CHARACTERISTICS OF THE ELEMENT ITSELF. THIS QUEST FOR CERTAINTY IS AN UNENDING TASK, AND A GOAL, IF ACHIEVED, WHICH WOULD DO MUCH TO FURTHER PROGRESS IN UNKNOWN AREAS.

DISCUSSION OF RISK AND UNCERTAINTY

GOVERNMENTAL CAPITAL EXPENDITURES ARE USUALLY EXPECTED TO PRODUCE BENEFITS WHICH FLOW BACK TO THE PUBLIC OVER A RELATIVELY LONG PERIOD OF TIME. BECAUSE OF THE INNOVATIVE NATURE AND THE MAGNITUDE OF GOVERNMENTAL INVESTMENTS, CONSIDERATIONS OF FUTURE PERFORMANCE SHOULD PLAY A PROMINENT ROLE IN THE ANALYSIS LEADING TO A PROJECT'S EVENTUAL ACCEPTANCE OR REJECTION. THESE CONSIDERATIONS OF POSSIBLE FUTURE OCCURRENCES ARE INQUIRIES INTO CONDITIONS OF UNCERTAINTY. AN EXAMPLE OF INVESTMENTS MADE IN AN UNCERTAIN

ENVIRONMENT MAY BE FOUND IN THE RECLAMATION ACT OF 1902. THIS ACT WAS A UNIQUE LEGISLATIVE DEVELOPMENT IN THAT TIME. ITS INDIVIDUAL PROVISIONS WERE DEVISED TO PERMIT THE IMPLEMENTATION AND BUILDING OF ENTERPRISES POSSESSING A HIGH DEGREE OF COMPLEXITY IN WHICH PIONEERING WAS INEVITABLY A CENTRAL FACTOR. AS LATER BECAME APPARENT, INHERENT TO THESE ENDEAVORS WERE LARGE FINANCIAL, HUMAN, AND AGRICULTURAL RISKS. AS DESCARTES STATED, A PRUDENT MAN GENERALLY TRUSTS ONLY THAT WHICH IS COMPLETELY KNOWN; YET, IN THE DYNAMIC SOCIETY OF TODAY, THE DECISION-MAKER IS FACED WITH A RAPID SEQUENCE OF PROBLEMS WHICH MUST BE SOLVED, EVEN THOUGH THE STATEMENT OF THE PROBLEM AND ITS SURROUNDING ENVIRONMENT IS OFTEN BASED UPON INCOMPLETE KNOWLEDGE. SINCE A STATE OF INCOMPLETE KNOWLEDGE COULD RESULT IN A LESS THAN OPTIMUM OR EVEN AN UNSATISFACTORY SOLUTION TO A PROBLEM, THE TASK OF THE DECISION-MAKER MUST BE TO MAKE A DISTINCT AND CONSTANT EFFORT TO BETTER UNDERSTAND THE BEHAVIORIAL CHARACTERISTICS ASSOCIATED WITH THE PROBLEM.

CERTAINTY, RISK, AND UNCERTAINTY ARE THREE SPECIFIC CONDITIONS WHICH SHOULD BE DIFFERENTIATED WHEN DISCUSSING POSSIBLE FUTURE OCCURRENCES; HOWEVER, ANY SUCH DIFFERENTIATION, PARTICULARLY BETWEEN RISK AND UNCERTAINTY, HAS BEEN RARE. A DECISION MADE UNDER CONDITIONS OF CERTAINTY IS PRESUMED TO RELATE EVERY POSSIBLE CONTEMPLATED COURSE OF ACTION TO A SPECIFIC OUTCOME WHICH WILL INEVITABLY OCCUR AS A CONSEQUENCE OF THE ACTION TAKEN. THUS, ONCE A SPECIFIC COURSE OF ACTION HAS BEEN CHOSEN, THE OUTCOME WILL BE KNOWN AND WILL BE ASSUMED

TO BE A FUNCTION OF THE CHOICE OF THE COURSE OF ACTION TAKEN.

IF, HOWEVER, A POSSIBLE CHOICE EXISTS NOT ONLY AS TO THE COURSE OF ACTION WHICH MAY BE TAKEN, BUT ALSO AS TO THE POSSIBLE OUTCOME RESULTING FROM ANY PARTICULAR COURSE OF ACTION, THE MODEL COULD THEN BE ONE CONTAINING AN ELEMENT OF RISK. A MODEL CONTAINING RISK COULD BE ONE IN WHICH, FOR EACH CONTEMPLATED COURSE OF ACTION, A DEFINITE SET OF POSSIBLE OUTCOMES EXISTED AND EACH OF THESE OUTCOMES HAD A KNOWN PROBABILITY ASSOCIATED WITH IT. SUCH A SITUATION WOULD BE ANALOGOUS TO THE COMMON FORMS OF GAMBLING.

FINALLY, IF THE CONTEMPLATED COURSES OF ACTION AGAIN HAD A SET OF SPECIFIC POSSIBLE OUTCOMES ASSOCIATED WITH THEM, AND THE PROBABILITIES ASSOCIATED WITH THESE OUTCOMES WERE UNKNOWN, THE DECISION-MAKER WOULD BE FACED WITH AN UNCERTAIN ENVIRONMENT. NOTE, HOWEVER, THAT THE CONDITION OF UNCERTAINTY WAS SPECIFIED TO BE ONE IN WHICH THE SET OF POSSIBLE OUTCOMES WAS COMPLETELY KNOWN. THUS, OUTCOMES WHICH MIGHT RESULT FROM WARS OR ACTS OF GOD WOULD NOT BE ACCOUNTED FOR IN THE MODEL, AN EXCLUSION WITH WHICH MOST DECISION-MAKERS WOULD, NO DOUBT, CONCUR.

SINCE THE DIFFERENTIATION BETWEEN CERTAINTY, RISK, AND UNCERTAINTY HAS BEEN DISCUSSED IN TERMS OF THE POSSIBLE OUTCOMES RESULTING FROM A CHOSEN COURSE OF ACTION, THE BROADEST CLASS OF PROBLEMS WOULD BE COMPRISED OF PROBLEMS INVOLVING UNCERTAINTY. DECISION PROBLEMS UNDER RISK WOULD THEN BE A SUBSET OF THE UNCERTAINTY SET SINCE INFORMATION

WOULD THEN BE AVAILABLE CONCERNING THE PROBABILITIES OF THE POSSIBLE OCCURRENCES. DECISION PROBLEMS UNDER CERTAINTY WOULD BE A SPECIAL CASE OF THE RISK SUBSET WHERE THE PROBABILITY OF THE OCCURRENCE OF A GIVEN OUTCOME APPROACHES ONE.

THE GOAL IN MOST REFINEMENTS OF ESTIMATING AND FORECASTING TECHNIQUES COULD BE MORE GENERALLY CATEGORIZED AS AN ATTEMPT TO REDUCE THE UNCERTAIN, UNCONTROLLED SITUATION TO A CONTROLLED SITUATION OF RISK RATHER THAN A QUEST FOR CERTAINTY. IN ORDER TO REDUCE UNCERTAINTY TO RISK, THE ANALYST MUST SEARCH FOR ADDITIONAL INFORMATION PERTINENT TO BEHAVIORIAL PATTERNS ASSOCIATED WITH THE PROBLEM AND ITS ENVIRONMENT, FOR THE LACK OF SUCH INFORMATION FORCES A PROBLEM TO BE CONSIDERED AS ONE OF UNCERTAINTY. THUS, THE PROBLEM DEFINITION, COMPLETE WITH INFORMATION CONCERNING AN EXHAUSTIVE SET OF POSSIBLE OUTCOMES, IS IMPORTANT TO DECISIONS MADE IN AN ENVIRONMENT CHARACTERIZED BY RISK AND UNCERTAINTY.

HISTORICALLY, ALL OF THE COMPONENTS OF THE BENEFIT-COST RATIO WERE CONSIDERED TO HAVE CERTAIN OUTCOMES. HOWEVER, SINCE THE COST AND BENEFIT COMPONENTS ARE DERIVED FROM ESTIMATES, THE EXISTENCE OF DEVIATIONS FROM THE EXPECTED VALUES OF THESE COMPONENTS WOULD BE EXPECTED. IF THE BENEFIT, OPERATION AND MAINTENANCE COST AND CONSTRUCTION COST TERMS WERE ALL ESTIMATED QUANTITIES, $\hat{B}_{JT}$, $\hat{O}_{JT}$, $\hat{K}_{JO}$ RESPECTIVELY, THE VARIATIONS IN THE EXPECTED VALUES OF THE ESTIMATES OF THESE QUANTITIES COULD BE REPRESENTED AS δ, θ, γ, RESPECTIVELY. THUS, THE GENERAL EXPRESSION FOR THE BENEFIT-

COST RATIO, INCLUDING BOTH ESTIMATED VARIABLES AND ESTIMATION VARIATION TERMS, COULD BE WRITTEN AS:

$$Z_J(\ \delta,\ \Theta,\ \gamma) = H(B_{JT} + \delta,\ O_{JT} + \Theta,\ K_{JO} + \gamma,\ I,\ T) \quad (4)$$

A DECISION AMONG J ALTERNATIVES WOULD THEN BE BASED UPON A DECISION RULE D WHICH WOULD BE UTILIZED TO FIND THE VALUE OF THE FUNCTION V_{JD} OVER ALL J ALTERNATIVES, WHERE

$$Z_D = G(V_{JD}\ [Z_J,\ I_J]\ ). \quad (5)$$

THE VALUE OF Z_D WOULD USUALLY BE CONSIDERED AT LEAST A FUNCTION OF THE EXPECTED VALUE OF THE BENEFIT-COST RATIO, Z_J, AND SOME VARIABILITY OR CONTINGENCY INDEX, I_J. SOME OF THE CHARACTERISTICS OF A CONTINGENCY INDEX WILL BE DISCUSSED IN THE NEXT CHAPTER.

IN ADDITION TO THE POSSIBLE VARIATIONS IN THE BENEFIT-COST RATIO CAUSED BY THE DEVIATIONS FROM THE EXPECTED VALUES OF THE BENEFIT AND COST COMPONENTS, DEVIATIONS WHICH COULD BE A DIRECT RESULT OF THE ESTIMATION PROCESS IN AN UNCERTAIN ENVIRONMENT, OTHER FACTORS CAN ALSO PRODUCE UNCERTAINTY IN THE FINAL OUTCOME. SOME OF THE MISCELLANEOUS CONTRIBUTORS TO THE UNCERTAINTY INHERENT TO A PREDICTION OF FUTURE OCCURRENCES, YET WHICH ARE USUALLY NOT INCLUDED IN THE ANALYTICAL DETERMINATION OF THE BENEFIT-COST RATIO, WILL BE BRIEFLY MENTIONED IN THE FOLLOWING DISCUSSION.

SOME FACTORS IN A MODEL ARE CONSIDERED TO BE KNOWN CONSTANTS DURING THE ANALYSIS. HOWEVER, WHEN SUCH FACTORS ARE TREATED AS CONSTANTS BECAUSE OF A LACK OF KNOWLEDGE ABOUT THEIR BEHAVIORIAL CHARACTERISTICS, THE INFLUENCE OF

VARIATIONS OF THESE CONSTANTS UPON THE OUTCOME COULD CAUSE THE PROJECT TO RANGE FROM A FIASCO TO A SUCCESS.[1] ONE FACTOR, WHICH IS USUALLY CONSIDERED TO BE A GIVEN CONSTANT, HAS BEEN THE LEVEL OF TECHNOLOGY THE PROPOSAL WILL FACE IN THE FUTURE. REGARDLESS OF OTHER FACTORS IN THE MODEL, TECHNOLOGICAL CHANGES OVER A HUNDRED-YEAR AVERAGE LIFE WOULD PRODUCE A RANGE OF BENEFIT-COST RATIO OUTCOMES RATHER THAN A UNIQUE VALUE.

ANOTHER FACTOR WHICH INTRODUCES AN ELEMENT OF UNCERTAINTY INTO A PREDICTION OF THE FUTURE OCCURRENCES IS THE INTER-DEPENDENCE OF GOVERNMENTAL CAPITAL EXPENDITURES, ESPECIALLY THE EXPENDITURES ON WATER RESOURCES. WHEN ONE CONSIDERS A RIVER BASIN SUCH AS THE MISSISSIPPI-MISSOURI BASIN, MANY PROJECTS WOULD BE INVOLVED, AND DECISIONS CONCERNING ANY PARTICULAR PROJECT COULD EASILY HAVE AN AFFECT UPON THE RESPONSES OF OTHER PROJECTS IN THE BASIN SYSTEM.

THESE FACTORS WHICH ARE NOT INCLUDED IN THE ANALYTICAL DETERMINATION OF THE BENEFIT-COST RATIO ARE USUALLY CALLED INTANGIBLES OR IRREDUCIBLES. IRREDUCIBLES POSSESS THE DISTINGUISHING CHARACTERISTIC THAT THEY CANNOT BE READILY TRANSLATED INTO THE UNITS BEING USED FOR THE EVALUATION.

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[1]FOR EXAMPLE, IN ONE NON-FEDERAL WATER-RESOURCE DEVELOPMENT PROJECT UNDERTAKEN IN 1941, ONE OF THE GIVEN CONSTANTS IN THE MODEL WAS AN INFESTATION OF 100 ACRES OF ALLIGATOR WEED IN THE RESERVOIR. "AS IT TURNED OUT, BY 1948, THOUSANDS OF ACRES WERE INFESTED, THE COST OF REMOVING THE VEGETATION WAS PROHIBITIVE AND INSTEAD OF THE ESTIMATED BENEFITS, AN EPIDEMIC OF MALARIA HAD BEEN REALIZED." (128, PP. 402-403)

THUS, THE IRREDUCIBLE FACTORS ASSOCIATED WITH A PROPOSAL OFTEN PRECLUDE ANY ABSOLUTE MEASURE OF BENEFITS AND COSTS; HOWEVER, RELATIVE MEASUREMENT OF BENEFITS AND COSTS BETWEEN PROJECTS MAY OFTEN BE DONE WITH A MUCH HIGHER LEVEL OF CONFIDENCE.[1]

THE WEIGHT ASSIGNED TO IRREDUCIBLES IN A DECISION SHOULD BE GIVEN CAREFUL CONSIDERATION; HOWEVER, THE NATURE OF IRREDUCIBLE FACTORS PRECLUDE CHECKING ONE'S JUDGMENT AGAINST ANY EXACTING STANDARD. THE WEIGHT FINALLY ASSIGNED TO THE IRREDUCIBLE FACTOR WOULD PROBABLY BE RELATIVE TO SOME FUNCTION OF THE DEGREE TO WHICH THE IRREDUCIBLE FACTOR MAY BE MEANINGFULLY DEFINED.

> IF SPECIFIC INTANGIBLE EFFECTS ARE CONSIDERED IMPORTANT ENOUGH TO INFLUENCE THE RECOMMENDATION FOR OR AGAINST A PROJECT DEVELOPMENT, THE VALUE ATTACHED TO SUCH SPECIFIC INTANGIBLE EFFECTS SHOULD BE INDICATED. THIS MAY RESULT IN EITHER CURTAILING OR EXPANDING THE SCALE OF DEVELOPMENT AS COMPARED TO THAT JUSTIFIED BY TANGIBLE EFFECTS. (124, P. 27)

HOWEVER, IN THE FINAL DECISION, HUMAN JUDGMENT MUST STILL PREVAIL.

> IF CONGRESS WERE TO RELY EXCLUSIVELY ON A BENEFIT-COST RATIO AS A MEASURE OF WHETHER OR NOT A PROJECT SHOULD BE ADOPTED, IT WOULD BE ABANDONING ITS RESPONSIBILITIES. SOME OF THE EFFORT TO PLACE MONETARY VALUES ON INDIRECT BENEFITS IS NOTHING SHORT OF LUDICROUS. (112, P. 51)

OTHER PROBLEMS ARE ALSO FACED BY THE ANALYST WHICH, WHILE NOT EXPRESSED IN ANALYTICAL TERMS, OFTEN INFLUENCE THE

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[1]ABSOLUTE MEASURES NEEDED TO DETERMINE THE MAGNITUDE OF A PROJECT'S OR PROJECTS' RELATIVE DESIRABILITY ARE OFTEN FOUND IN A MORE POLITICAL WAY.

PROPOSAL PRESENTED TO THE DECISION-MAKER. PRESSURES EXERTED UPON THE PROJECT ANALYST AND THE DECISION-MAKER BY TIME DEADLINES, LIMITATIONS OF INVESTIGATORY FUNDS, AND POLITICAL CONSIDERATIONS ARE USUALLY TREATED AS IRREDUCIBLES, IF NOT IGNORED COMPLETELY.

THE PRESSURE OF TIME IS A FORCE WHICH TENDS TO AMPLIFY THE CONFLICTS BETWEEN THE THEORIES PROPOSED IN ACADEMIC DISCUSSIONS AND THE OPERATIONAL TECHNIQUES UPON WHICH DECISIONS ARE ACTUALLY BASED. IT IS A RARE PROJECT WHICH DOES NOT HAVE A FIXED TARGET DATE WHEN ALL APPROPRIATE INFORMATION MUST BE AVAILABLE AND PROPERLY CATEGORIZED, AND AFTER WHICH ADDITIONAL INVESTIGATION IS OF QUESTIONABLE VALUE. THIS TARGET DATE, LIKE THE SWORD OF DAMOCLES, INEVITABLY HANGS OVER THE INVESTIGATOR AND INCREASES THE PROBABILITY THAT ANY DECISION WILL BE MADE ACCORDING TO THE FOLLOWING PROPOSITION.

> THE AMOUNT OF PERTINENT INFORMATION AVAILABLE UPON WHICH TO BASE A DECISION IS DIRECTLY PROPORTIONAL TO THE AMOUNT OF TIME AVAILABLE TO GATHER INFORMATION BEFORE THE DECISION MUST BE MADE.

OR ONE MIGHT STATE THIS PROPOSITION CONVERSELY AS:

> THE DEGREE TO WHICH A DECISION IS BASED UPON INTUITION IS DIRECTLY PROPORTIONAL TO THE TIME PRESSURES IMPOSED UPON THE DECISION-MAKERS.

IN ADDITION TO THE PRESSURES OF TIME ON THE STUDY, THE LACK OF MONEY AVAILABLE FOR THE STUDY HINDERS THE ANALYST, FOR NOT ONLY IS IT COSTLY TO OBTAIN ANY DATA, BUT IT BECOMES

INCREASINGLY EXPENSIVE TO OBTAIN EACH ADDITIONAL INCREMENT OF INFORMATION WHICH WOULD RESULT IN REFINEMENT OF THE DECISION CRITERIA. AS A RESULT OF THESE PRESSURES, THE ENGINEER IS OFTEN THWARTED IN HIS ATTEMPT TO MAKE AN EFFECTIVE ANALYSIS OF THE PROBLEM, THWARTED NOT THROUGH THE LACK OF SKILL OR TECHNIQUES, BUT BECAUSE OF TIME AND MONEY LIMITATIONS.[1]

POLITICAL CONSIDERATIONS MAY ALSO BE A FACTOR WHICH AFFECTS AN ANALYSIS. BALANCED REGIONAL DEVELOPMENT IS ONE FACET OF POLITICAL PRESSURE OFTEN ENCOUNTERED NOT ONLY IN THE TRADITIONAL PUBLIC WORKS PROJECTS, BUT ALSO IN THE AREA OF DEFENSE AND SPACE RESEARCH.

> I THOUGHT IT WAS A GREAT COMPLEMENT TO THE CORPS OF ENGINEERS THAT WAS OFFERED ON THE FLOOR OF THE HOUSE YESTERDAY WHEN MEMBER AFTER MEMBER ROSE TO GET A SURVEY IN THE BILL SOMEHOW, SO THAT YOU COULD DO SOME WORK IN THAT PARTICULAR MEMBER'S DISTRICT. ... I THOUGHT THE EAGERNESS THAT WAS SHOWN ON THE PART OF THE MEMBERS TO HAVE YOU COME TO THEIR DISTRICT AND DO WORK THERE SHOWED THAT THEY HAD FAITH AND CONFIDENCE IN YOU. (110, P. 81)

UNFORTUNATELY, DUE TO THE PRESENT ENGINEERING AND ECONOMIC LIMITATIONS, LITTLE MAY BE SAID ABOUT REDUCING PRESSURES TO EVEN THE LEVEL OF SUBJECTIVE DEFINITION OF IRREDUCIBLES. HOWEVER, THE EFFECTS OF PRESSURES OF TIME, COST, AND POLITICS COULD RESULT IN THE INTRODUCTION OF BIAS INTO THE STUDY IF THESE PRESSURES WERE NOT RECOGNIZED AND COMPENSATED FOR.

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[1]FOR A DETAILED DISCUSSION OF THE EFFECT OF THESE PRESSURES UPON A DECISION, SEE MORRIS (49, PP. 399-414).

ALL ESTIMATES MUST BE BASED UPON SOME COLLECTION OF RELEVANT DATA, AND IN THE CASE OF FEDERAL WATER-RESOURCE PROJECTS, THESE DATA ARE USUALLY OBTAINED FROM FIELD STUDIES AND FROM ECONOMIC DATA GATHERED BY OTHER GOVERNMENTAL AGENCIES. UNFORTUNATELY, A SIGNIFICANT DEGREE OF INACCURACY IS INHERENT TO MANY OF THESE DATA.[1] FOR EXAMPLE, THE

> ...BASIC DATA FOR THE HYDROLOGIC, AGRICULTURAL, AND ECONOMIC ELEMENTS OF PROJECT BENEFIT EVALUATION ARE OFTEN GROSSLY DEFICIENT,

OR SOMETIMES NOT EVEN AVAILABLE (98, P. 1293).

> ... [I]N THE ABSENCE OF FIRM BASIC DATA, AND SOMETIMES EVEN IN THE PRESENCE OF SUCH DATA, THE JUDGMENT OF THE CONSTRUCTION AGENCY PERSONNEL TENDS TOWARDS A SIGNIFICANT BIAS IN FAVOR OF PROJECT JUSTIFICATION. EVEN SEEMINGLY MINOR "OPTIMISM" IN ESTIMATING EACH OF SEVERAL FACTORS MAY LEAD TO A LARGE INFLATION OF THE FINAL RESULT, FOR SOME OF THE BITS OF OPTIMISM HAVE A CUMULATIVE OR MULTIPLIER EFFECT IN A SERIES. (98, P. 1293)

PROBABLY A PORTION OF THIS BIAS IS THE RESULT OF EMPLOYEE ENTHUSIASM TOWARD THEIR JOBS. WHILE AN ENTHUSIASTIC ATTITUDE SHOULD NOT NECESSARILY BE CONDEMNED, ANY BIAS IN THE DECISION CRITERIA STEMMING FROM THIS ENTHUSIASM SHOULD BE RECOGNIZED.

> FOR MORE REASONS THAN MERE ESPRIT THE CORPS [OF ENGINEERS] IS "WORK HUNGRY." ... [S]INCE THERE IS NOT SUSTAINING APPROPRIATION FOR FIELD STAFF, [THE STAFF] DO[ES] NOT GET PAID IF THEIR SALARIES CANNOT BE CHARGED TO SOME PUBLIC-WORKS PROGRAM. BECAUSE OF THIS STARK FACT OF LIFE EVERY MEMBER OF THE CORPS, OFFICER OR CIVILIAN, IS ALERT TO SUGGEST, FIND, INITIATE, OR OTHERWISE CREATE A ROLE FOR THE CORPS IN ANY PROJECT

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[1]THIS POINT IS DISCUSSED IN DETAIL BY MORGENSTERN (48).

> PROPOSED OR HINTED AT THAT WILL SERVE TO KEEP THE EMPLOYEES OCCUPIED. (65, P. 127)

SUCH A STATEMENT COULD CERTAINLY IMPLY A FERTILE FIELD IN WHICH TO PRODUCE BIAS.

FINALLY, BIAS IS NOT PECULIAR TO ANY ONE OF THE CLASSIFICATIONS OF OUTCOMES, FOR BIAS HAS BEEN FOUND UNDER CONDITIONS OF CERTAINTY, RISK, AND UNCERTAINTY. IN ADDITION, BIAS MAY BE INTRODUCED INTO THE DECISION CRITERIA IN WAYS OTHER THAN THROUGH THE BASIC DATA, SUCH AS THE INCLUSION OF INDIRECT BENEFITS IN THE BENEFIT-COST RATIO. WHILE THESE OTHER SOURCES OF BIAS WILL NOT BE DISCUSSED IN THIS STUDY, THEIR EXISTENCE SHOULD BE NOTED, FOR NO ADJUSTMENT FOR RISK OR UNCERTAINTY MAY MAKE UP FOR DIFFICIENCIES IN KNOWLEDGE OR THE PRESENCE OF BIAS IN THE ANALYSIS OF A PROPOSED EXPENDITURE.

COMPENSATION FOR ESTIMATION UNCERTAINTY

ADJUSTMENTS IN DECISION CRITERIA TO ALLOW FOR AN UNCERTAIN ENVIRONMENT ARE INTENDED TO COMPENSATE FOR THE HAZARDS WHICH INTERVENE BETWEEN THE TIME OF RESOURCE COMMITMENT AND THE TIME WHEN THE FINAL BENEFITS ACCRUE TO THE INVESTOR. FIVE PRINCIPAL METHODS HAVE BEEN COMMONLY USED TO COMPENSATE FOR UNCERTAINTY, AND THESE METHODS ARE:

1. COMPENSATION THROUGH INFORMAL JUDGMENT,
2. LIMITATION ON THE PERIOD OF ANALYSIS,
3. INCLUSION OF A SPECIFIC AND DIRECT SAFETY ALLOWANCE,
4. UTILIZATION OF CASE-BY-CASE PROBABILITY MULTIPLIERS,

5. VARIATION OF THE BASIC INTEREST RATE OR RATES.[1]

THE FIRST AND MOST COMMON METHOD OF COMPENSATING FOR UNCERTAINTY HAS BEEN THE USE OF INFORMAL JUDGMENT. WHILE THIS TREATMENT OF UNCERTAINTY IS QUITE COMMON, JUDGMENT IS NECESSARILY SO DEPENDENT UPON THE INDIVIDUAL THAT IT COULD WELL HAVE THE LEAST CHANCE OF ACHIEVING THE DESIRED, LONG-RUN RESULT, THAT OF PREDICTING THE CORRECT OUTCOME.

SECOND, THE IMPOSITION OF A LIMITATION ON THE PERIOD OF ANALYSIS IS MORE COMMONLY DONE IN THE PRIVATE INVESTMENT SECTOR, THROUGH THE USE OF PAYOUT ANALYSIS, THAN IN THE CONSIDERATION OF GOVERNMENT INVESTMENTS. WHILE SUCH A LIMITATION WILL INSURE AGAINST, OR MINIMIZE, UNCERTAINTY IN THE DISTANT FUTURE, IT ALSO ACTS TO DISCOURAGE MARGINAL INVESTMENTS FOR EXTRA CAPACITY, FOR NO BENEFIT CREDIT WILL BE RECOGNIZED WHICH ACCRUES TO THE INVESTOR AFTER THE ARBITRARY TIME CONSTRAINT. THUS, IF ONE WERE TO HYPOTHESIZE THAT GOVERNMENT INTERVENTION WOULD BE DESIRABLE IN LONG-LIVED INVESTMENTS OF HIGH CAPITAL INTENSITY, A LIMITATION PLACED UPON THE PERIOD OF ANALYSIS WOULD FUNCTION COUNTER TO THIS HYPOTHESIS.[2]

THIRD, THE INCLUSION OF SPECIFIC AND DIRECT SAFETY ALLOWANCES IN THE PREDICTION OF FUTURE OCCURRENCES IS A

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[1]TEXTS ON ENGINEERING ECONOMY (24, 49, 66, 132) CONTAIN DETAILED DESCRIPTIONS CONCERNING THE OPERATIONS OF THESE METHODS.

[2]THIS METHOD IS FURTHER DISPOSED OF BY ECKSTEIN (15, PP. 81-86).

METHOD WITH ITS ROOTS IN ANTIQUITY. WHILE SUCH A METHOD DOES PROVIDE AN INDIRECT ALLOWANCE FOR RISKS AND UNCERTAINTIES WHICH ARE NOT TIME RELATED, THE ACCUMULATION OF THESE SAFETY FACTORS IS A REAL DANGER, AND THEIR USE CONCURRENT WITH INTEREST RATE ADJUSTMENTS MAY RESULT IN A DUPLICATION OF UNCERTAINTY COMPENSATION.

> ALL OF THE HYDROLOGIC PROCESSES WHICH TEND TO AMPLIFY [THE] FREQUENCY AND EXTENT OF FLOODING ARE CARRIED OVER INTO THE PROCESSES USED IN DETERMINING DAMAGES AND THE MARGIN OF ERROR IS INCREASED. THE PRACTICE OF LEANING CONSISTENTLY TOWARD THE LIBERAL SIDE IN THE COMPUTATION OF DAMAGE HAS THE EFFECT OF ACCUMULATING ANOTHER SERIES OF SMALL DOUBTFUL VALUES INTO A TOTAL MARGINAL PRODUCT THAT MAY HAVE A CONSIDERABLE EFFECT ON ECONOMIC JUSTIFICATION. (23, P. 11)

THUS WHILE THE INCLUSION OF A SAFETY ALLOWANCE MAY BE ACCEPTABLE FOR SPECIFIC PROJECTS, IN GENERAL THIS METHOD TENDS TO PRODUCE ERRONEOUS OVERESTIMATES OF BOTH PROJECT COSTS AND BENEFITS.

FOURTH, A CASE-BY-CASE DETERMINATION OF THE POSSIBLE SET OF OUTCOMES ASSOCIATED WITH A GIVEN COURSE OF ACTION AND OF THE PROBABILITIES ASSOCIATED WITH THE OCCURRENCE OF THESE OUTCOMES IS A LEGITIMATE METHOD TO COMPENSATE FOR RISK. HOWEVER, FOR THIS METHOD TO BE EFFECTIVE, THE POSSIBLE FUTURE OUTCOMES MUST BE WELL DEFINED AND THE ANALYST MUST POSSESS SUFFICIENT INFORMATION WITH WHICH TO DETERMINE THE PERTINENT PROBABILITIES, INFORMATION, THE LACK OF WHICH LIMITS THE APPLICABILITY OF THIS METHOD TO A

FEW SPECIFIC TYPES OF PROJECTS.[1]

A FIFTH AND FINAL METHOD TRADITIONALLY USED TO COMPENSATE FOR RISK AND UNCERTAINTY HAS BEEN THE INCLUSION OF A SPECIFIC ALLOWANCE IN THE INTEREST RATE.

> THE VALUES ATTACHED TO BENEFITS AND COSTS AT THEIR TIME OF ACCRUAL CAN BE MADE COMPARABLE ONLY AFTER COVERSION TO AN EQUIVALENT BASIS FOR TIME AND DEGREE OF CERTAINTY OF OCCURRENCE. INTEREST AND DISCOUNT RATES AND RISK ALLOWANCES PROVIDE A MEANS FOR GIVING MONETARY EXPRESSION TO DIFFERENCES IN THE TIME OCCURRENCES OF BENEFITS AND COSTS. (124, P. 22)

UNCERTAINTY COMPENSATION THROUGH THE USE OF THE INTEREST RATE RECOGNIZES THE UNKNOWN FUTURE BEHAVIORIAL CHARACTERISTICS OF A PROPOSAL BY HEAVILY DISCOUNTING THE FUTURE AND PENALIZING CAPITALLY INTENSIVE PROJECTS, AS ONE WOULD EXPECT WHEN RESOURCES WILL BE COMMITTED IN SUCH AN IRREVOCABLE WAY.

THE RATE OF INTEREST ASSOCIATED WITH AN INVESTMENT IS GENERALLY CONSIDERED TO BE A FUNCTION OF:

1. THE PURE OR RISK-FREE COST OF BORROWING, OFTEN CALLED THE PURE INTEREST RATE,
2. THE RISK INVOLVED,
3. THE ELEMENT ASSOCIATED WITH MANAGEMENT EXPENSES NOT COVERED IN THE TWO PREVIOUS CATEGORIES.

FOR EXAMPLE, IN THE EVALUATION OF WATER-RESOURCE PROJECTS THE RECOMMENDED INTEREST RATE HAS BEEN A RATE EQUAL TO THE YIELD

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[1]FOR ADDITIONAL DISCUSSION ON THE USE OF PROBABILITY MULTIPLIERS IN THE ANALYSIS OF WATER-RESOURCE PROJECTS, SEE MCKEAN (44, PP. 58-103) AND GRANT (22, PP. 260-268).

OF LONG-TERM GOVERNMENT BONDS, AVERAGED OVER A SUFFICIENTLY LONG PERIOD OF TIME TO NEUTRALIZE ANY INFLUENCES OF CYCLICAL FLUCTUATIONS.[1] THIS YIELD ON LONG-TERM FEDERAL SECURITIES PROBABLY REPRESENTS ONE OF TODAY'S BEST EXAMPLES OF A RISK-FREE INVESTMENT. THUS, THE TWO AND ONE-HALF PER CENT RATE SHOULD NOT BE EXPECTED TO INCLUDE ANY APPRECIABLE ADJUSTMENT FOR RISK AND UNCERTAINTY, AND SUCH AN ADJUSTMENT IS EXPECTED TO BE MADE PRIOR TO THE DISCOUNTING OPERATION.

> IF SUCH AN ALLOWANCE [FOR RISK AND UNCERTAINTY IN THE INDIVIDUAL ESTIMATES] IS NOT POSSIBLE, A COMPONENT FOR RISK SHOULD BE INCLUDED IN THE INTEREST RATE... (124, P. 25)

THE PORTION OF THIS QUOTATION, THAT IS, THAT "A COMPONENT FOR RISK SHOULD BE INCLUDED IN THE INTEREST RATE," FORMS PART OF THE BASIS FOR MUCH OF THE DISCUSSION AS TO WHAT AN APPROPRIATE RATE OF INTEREST ACTUALLY SHOULD BE WHEN EVALUATION OF GOVERNMENTAL CAPITAL EXPENDITURES IS DONE.[2] IN ADDITION TO THE

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[1] A TWO AND ONE-HALF PER CENT RATE HAS BEEN ACCEPTED AS A STANDARD FOR MOST EVALUATIONS PERFORMED BY GOVERNMENT AGENCIES. HOWEVER, THIS RATE WAS ONLY EQUAL TO THE AVERAGE YIELD OF LONG-TERM GOVERNMENT BONDS FOR A SHORT PERIOD SUBSEQUENT TO WORLD WAR II.

[2] AN INTERESTING PROPOSAL HAS BEEN ADVANCED WHICH USES A RATE OF INTEREST WHEN EVALUATING BENEFITS WHICH DIFFERS FROM THAT USED WHEN EVALUATING COSTS (24). THE ARGUMENT FOR THE USE OF A DUAL RATE OF INTEREST WAS BASED UPON THE DUAL ROLE WHICH THE GOVERNMENT PLAYS IN CONNECTION WITH WATER RESOURCE PROJECTS. IN THE CONSTRUCTION, OPERATION, AND MAINTENANCE OF A PROJECT THE GOVERNMENT ASSUMES THE ROLE OF A BUYER OF RESOURCES. UNCERTAINTY RELATIVE TO THE FINAL OUTCOME WOULD PROVIDE A DISUTILITY WHICH WOULD TEND TO INCREASE THE COST OVER THAT EXPECTED WITH LESS UNCERTAINTY. THE INTEREST RATE WOULD THEN BE DECREASED FOR THESE ACTIVITIES TO COMPENSATE FOR THE BUYER'S DISUTILITY AND THE LOWER DEGREE OF UNCERTAINTY

INCLUSION OF A RISK COMPONENT, MOST CRITICS OF THE CURRENTLY USED INTEREST RATE FEEL THAT THE SOCIAL COST OF CAPITAL SHOULD ALSO BE INCLUDED WHEN DETERMINING THE CORRECT INTEREST RATE.[1] HOWEVER, SINCE THIS STUDY WAS INTENDED TO BE AN INQUIRY INTO THE DEVIATIONS ABOUT THE ESTIMATED EXPECTED VALUES OF THE INDIVIDUAL BENEFIT AND COST COMPONENTS AND THE EFFECT OF THESE DEVIATIONS UPON ONE OF THE DECISION CRITERIA NOW IN USE, THE BENEFIT-COST RATIO, THE QUESTION OF THE PROPER INTEREST RATE IS NOT PERTINENT. THEREFORE, THE TWO AND ONE-HALF PER CENT INTEREST RATE WILL BE ASSUMED TO BE VALID FOR THE REMAINDER OF THIS INVESTIGATION.

FINALLY, IT SHOULD BE NOTED THAT THE INCLUSION OF ADJUSTMENTS FOR RISK AND UNCERTAINTY IN THE ECONOMIC MODEL WILL NOT ALWAYS BE NECESSARY. FOR MINOR PROBLEMS, ONE MAY REASONABLY ASSUME CONDITIONS OF CERTAINTY, GIVEN THAT:

1. THE AMOUNT OF RISK IS SMALL;
2. THE DIFFICULTY OR EXPENSE OF INCLUDING UNCERTAINTY ADJUSTMENTS IN THE ANALYSIS IS SUFFICIENT, RELATIVE TO

(FOOTNOTE 2 CONTINUED) USUALLY ASSOCIATED WITH COSTS, FOR COSTS GENERALLY HAVE A SHORTER, MORE EASILY DEFINED TIME SERIES. IN THE GOVERNMENT'S ROLE AS A PROVIDER OF BENEFITS FROM A PROJECT, IT ACTS AS A SELLER, AND THE PRICE EXPECTATIONS UNDER UNCERTAINTY WILL BE LESS THAN THE VALUE UNDER A CERTAIN ENVIRONMENT. THUS, A LARGER INTEREST RATE WOULD BE USED TO DISCOUNT THE LONGER TIME SERIES USUALLY ASSOCIATED WITH BENEFITS. THE NET RESULT OF THIS PROPOSAL WOULD BE TO ADJUST THE INTEREST RATE USED IN EVALUATING COSTS AND BENEFITS IN THE OPPOSITE DIRECTION, THEREBY REDUCING A PROPOSAL'S BENEFIT-COST RATIO.

[1]FOR A COMPREHENSIVE DISCUSSION OF VARIOUS PROPOSED INTEREST RATES, SEE (15, 22, 23, 24, 28, 36, 38, 44).

THE MAGNITUDE OF THE INVESTMENT; THAT THE USE OF MANAGERIAL JUDGMENT BECOMES PREFERABLE;

3. THE INCLUSION OF RISK OR UNCERTAINTY IN THE ANALYSIS COULD NOT AFFECT THE DECISION (49, P. 46).

CAPITAL EXPENDITURES OF GOVERNMENTAL ORGANIZATIONS ARE, HOWEVER, GENERALLY OF SUFFICIENT MAGNITUDE AND COMPLEXITY TO RELEGATE THE ASSUMPTION OF AN ENVIRONMENT OF CERTAINTY TO THE STATUS OF AN EXCEPTION RATHER THAN A RULE.

ECONOMIC EVALUATIONS OF CAPITAL EXPENDITURES IN A NONPROFIT ENVIRONMENT INCORPORATE ALL FIVE OF THE METHODS OF UNCERTAINTY COMPENSATION DISCUSSED IN THIS CHAPTER, INHERITING BOTH THEIR STRENGTHS AND WEAKNESSES. HOWEVER, EX POST FACTO ANALYSES OF PAST PERFORMANCES OF ESTIMATIONS MADE IN CONNECTION WITH FEDERAL CAPITAL EXPENDITURES INDICATE THAT THE ESTIMATES LEADING TO THE FORMULATION OF DECISION CRITERIA WERE UNRELIABLE. THESE ANALYSES SEEMED TO IMPLY THAT ESTIMATING TECHNIQUES IN USE NETHER ADEQUATELY REFLECTED THE POSSIBLE OUTCOMES NOR THE UNCERTAINTY ASSOCIATED WITH THESE OUTCOMES. IT IS THE CONTENTION OF THIS STUDY THAT MUCH OF THIS POOR ESTIMATION RECORD WOULD BE ATTRIBUTABLE TO THE FAILURE TO CONSIDER THE FREQUENCY DISTRIBUTION ASSOCIATED WITH THE PREDICTED EXPECTED VALUES. THE FOLLOWING PARAGRAPHS WILL DISCUSS SOME OF THE POSSIBLE MISCONCEPTIONS ASSOCIATED WITH THE USE OF SINGLE VALUE ESTIMATES, ESTIMATES WHICH TEND TO DISREGARD POSSIBLE DEVIATIONS FROM THESE EXPECTED VALUES.

IT IS OF COURSE NO SECRET THAT FEDERAL AGENCIES,

> ..., HAVE HAD A NOTORIOUS HISTORY OF OVEROPTIMISM EVEN ON FACTUAL MATTERS RELATING TO PROSPECTIVE COSTS AND BENEFITS, QUITE ASIDE FROM THEIR CONCEPTUAL ERRORS WHICH DOUBLE-COUNT OR OTHERWISE INFLATE THEIR ESTIMATES. (24, P. 145)

IF ONE WERE TO ASSUME THAT THE ESTIMATES OF COSTS AND BENEFITS WOULD BE MADE AS ACCURATELY AS PERMITTED BY EXISTING TECHNOLOGY, THEN UNCERTAINTY MUST HAVE BEEN PRESENT TO CAUSE THIS RECORD OF DEVIATIONS FROM THE ORIGINAL PREDICTIONS. YET, INVESTMENT CRITERIA WERE TO HAVE EMBODIED SOME ADJUSTMENT FOR RISK WHICH WAS TO INSURE THAT, CETERIS PARIBUS, UNDERTAKINGS WHICH WERE RELATIVELY SECURE IN THEIR OUTCOMES WOULD BE FAVORED OVER OTHERS WHICH CONTAINED A HIGHER DEGREE OF RISK.

A POINT OFTEN OVERLOOKED IS THAT THERE ARE TWO DIFFERENT AND DISTINCT KINDS OF ADJUSTMENT FACTORS FOR RISK AND UNCERTAINTY (28, P. 139). THE FIRST OF THESE FACTORS, AND ONE WHICH IS IGNORED BY MOST ANALYSTS COMPLETELY, IS THE EXPECTED VALUE ADJUSTMENT. THIS ADJUSTMENT IS INTENDED TO ACCOUNT FOR THE POSSIBLE DEVIATIONS OF ESTIMATES FROM THEIR EXPECTED VALUES. IN OTHER WORDS THIS ADJUSTMENT SHOULD IN SOME WAY ACCOUNT FOR THE FREQUENCY DISTRIBUTION ASSOCIATED WITH EACH ESTIMATE, AND IN THIS WAY, RECOGNIZE THE VARIANCE ABOUT THE ESTIMATED EXPECTED VALUE. FURTHER DISCUSSION BY PROVIDING THE DECISION-MAKER WITH INFORMATION CONCERNING THIS ADJUSTMENT FACTOR WILL BE PROVIDED IN SUBSEQUENT CHAPTERS.

THE SECOND TYPE OF ADJUSTMENT FACTOR COULD BE CLASSIFIED AS A RISK-AVERSION FACTOR. THIS FACTOR WOULD BE AN AGGREGATION

OF MANY VARIABLES AND COULD CONCEIVABLY BE EITHER POSITIVE OR NEGATIVE, DEPENDING ON AN INDIVIDUAL'S WILLINGNESS TO ASSUME RISK. IN ADDITION THIS FACTOR COULD INCLUDE A CONSIDERATION OF THE RISK-FREE INTEREST RATE TO ALLOW FOR THE TIME VALUE OF MONEY AND TO COMPENSATE THE CAPITAL MANAGERS FOR THEIR EFFORT. THE USE OF A RISK-AVERSION FACTOR AS A DISCOUNT RATE HAS BEEN THE CENTER OF CONTROVERSY FOR A NUMBER OF YEARS.

> THE LOGICALLY PUREST METHOD, ..., IS NOT TO INCORPORATE THE RISK ALLOWANCE IN THE DISCOUNT RATE AT ALL. INSTEAD, THE COSTS AND BENEFITS WOULD BE ESTIMATED IN SUCH A WAY AS TO HAVE EACH ANNUAL FIGURE REPRESENT AT CURRENT PRICE LEVELS THE EXPECTED VALUE OF ITS PROBABILITY DISTRIBUTION, IGNORING RISK AVERSION. ... THESE RISK-ADJUSTED COSTS AND BENEFITS COULD THEN BE DISCOUNTED AT THE "PURE" OR RISKLESS RATE OF INTEREST, THE LATTER INCLUDING A DOWNWARD CORRECTION FOR ANTICIPATED MONETARY DEPRECIATION. (28, P. 144)

THIS METHOD IS LOGICALLY SUPERIOR TO INCORPORATING THE RISK ADJUSTMENT IN THE DISCOUNT RATE, BECAUSE THE DISCOUNT RATE IS ASSUMED TO BE STRICTLY A FUNCTION OF TIME, AND UNCERTAINTY ASSOCIATED WITH EXPECTED VALUES DOES NOT NECESSARILY ADHERE TO SUCH AN ASSUMPTION. THE SUBSTANCE OF THIS ARGUMENT COULD BE USED TO JUSTIFY THE PRESENT TWO AND ONE-HALF PER CENT INTEREST RATE USED BY THE GOVERNMENT; HOWEVER, NO JUSTIFICATION IS YET EVIDENT FOR IGNORING THE EXPECTED VALUE ADJUSTMENT.

RISK WAS PREVIOUSLY DEFINED AS A SET OF KNOWN OUTCOMES, WITH A KNOWN PROBABILITY ASSOCIATED WITH EACH OUTCOME, RESULTING FROM A GIVEN COURSE OF ACTION. A RULE OF THUMB TO

TEST WHETHER ONE WAS DEALING WITH RISK OR UNCERTAINTY WOULD THEN BE, DUE TO THE WELL-DEFINED NATURE OF RISK, WHETHER OR NOT ONE COULD INSURE AGAINST AN ADVERSE OUTCOME. THE PRINCIPLE OF INSURANCE IS THAT OF POOLING RISKS. IN A RISK DOMINATED ENVIRONMENT, THE LAW OF LARGE NUMBERS DICTATES THAT DEVIATIONS FROM AN EXPECTED OCCURRENCE WOULD CANCEL, WHEN MANY PROJECTS ARE CONSIDERED, AND DUE TO THIS CANCELLATION EFFECT, IT HAS BEEN ARGUED THAT THE GOVERNMENT WOULD BE A SUPERIOR RISK TAKER.[1] THIS SUPERIORITY IN THE ASSUMPTION OF RISK WOULD BE DUE TO THE GOVERNMENT'S MANY DIVERSE INVESTMENTS, AND, THEREFORE, NO ADJUSTMENT FOR RISK NEED BE MADE IN THE INTEREST RATE AND ONLY EXPECTED VALUES NEED BE FOUND FOR ESTIMATED VALUES OF BENEFITS AND COSTS.

IN THE CONTEXT OF PUBLIC INVESTMENT, ONE MAY FIND CONSIDERABLE JUSTIFICATION FOR RISK CANCELLATION. THE RISK ON INVESTMENT, FROM THE VIEWPOINT OF THE WHOLE ECONOMY, SHOULD BE CONSIDERABLY SMALLER THAN THE RISK ON AN INDIVIDUAL PROJECT. THUS, IT MAY BE ARGUED THAT INVESTING IN HIGH-RISK, HIGH RETURN PROJECTS WILL ULTIMATELY ADD TO THE NATIONAL

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[1] THE LAW OF LARGE NUMBERS STATES THAT IF:
$F_1, F_2, \ldots, F_3$ ARE INDEPENDENT FUNCTIONS WITH AN EXPECTED VALUE OF F_I, $E[F_I] = A$ AND THE VARIANCE OF F_I, $V[F_I] = B^2$ FOR ALL I, AND $H_N = (F_1 + \ldots + F_N)/N$, THEN FOR ANY K
$\Pr\left[|H_N - A| > K\right] \leq \frac{B^2}{NK^2}$ OR $\Pr\left[|H_N - A| > K\right] \to 0$, AS N TENDS TO GO TO INFINITY (32, P. 174).

INCOME IN GREATER PROPORTION THAN INVESTING IN LOW-RISK, LOW RETURN VENTURES.

THIS STUDY WAS NOT INTENDED TO REFUTE THIS ARGUMENT. HOWEVER, ANALYSIS OF PAST EXPERIENCE, AS SHOWN IN A SUBSEQUENT CHAPTER, HAS NOT PROVIDED CONCLUSIVE EVIDENCE THAT A RISK-CANCELLATION EFFECT HAS TAKEN PLACE. TWO FACTORS CONTRIBUTING TO THIS APPARENT THWARTING OF RISK CANCELLATION SEEM TO BE PREDOMINANT. FIRST, ESTIMATES USED TO PREDICT FUTURE OUTCOMES DO NOT SEEM TO HAVE BEEN BASED UPON EXPECTED VALUES, AND SECOND, NO ASSURANCE IS PROVIDED THAT ENOUGH FEDERAL WATER-RESOURCE PROJECTS, FOR EXAMPLE, HAVE BEEN CONSTRUCTED TO BRING THIS POOLING EFFECT INTO PLAY.

FINALLY, THE INSURANCE PRINCIPLES APPLICABLE TO THE ENTIRE ECONOMY DO NOT ALWAYS SEEM FAIR TO INDIVIDUAL PROJECTS, FOR THESE PRINCIPLES WOULD INVOLVE A SACRIFICE IN AN EXPECTED RETURN FOR A GREATER SECURITY OF RETURN. IN ADDITION THE FACT THAT THE GOVERNMENT CAN POOL MANY RISKS DOES NOT IN ANY WAY IGNORE THE EFFECT OF THE RISK OF FAILURE UPON THE EXPECTED OUTCOME FOR ANY PROJECT OR GROUP OF PROJECTS, FOR AN INVESTMENT WHICH WILL DOUBLE ITSELF IN A GIVEN PERIOD OF TIME WITH A PROBABILITY OF ONE-HALF OR BE LOST ENTIRELY STILL HAS AN EXPECTED GAIN OF ZERO.

THROUGHOUT THE PRECEDING DISCUSSION, WHEN REFERENCE WAS MADE TO ESTIMATED VALUES, THE ASSUMPTION WAS IMPLIED THAT UNDER AN UNCERTAIN ENVIRONMENT THESE ESTIMATES WERE THE EXPECTED VALUE OF SOME FREQUENCY DISTRIBUTION. HOWEVER,

ANALYSES OF PAST EXPERIENCES CAST DOUBT AS TO WHETHER OR NOT THE EXPECTED VALUES OF THE ESTIMATED QUANTITIES WERE ACTUALLY WHAT HAS BEEN ESTIMATED. RATHER THAN THE EXPECTED VALUES, THE ESTIMATORS MIGHT WELL HAVE BEEN FINDING THE MODE OF THE FREQUENCY DISTRIBUTIONS.

ESTIMATES, ESPECIALLY COST ESTIMATES, HAVE USUALLY BEEN BASED UPON THE MOST PROBABLE VALUE, THAT IS, THE VALUE WHICH WOULD OCCUR MOST FREQUENTLY IF MANY SUCH PROJECTS WERE BUILT. THIS MOST PROBABLE VALUE IS REFERRED TO AS THE MODE OF THE FREQUENCY DISTRIBUTION. IT WOULD BE A RARE ESTIMATOR WHO WOULD DERIVE AN EXPECTED VALUE FOR THE ESTIMATE OF A PARTICULAR FACTOR BY CONSIDERING THE PROBABLE DISTRIBUTION OF OUTCOMES FOR EACH ESTIMATED FACTOR. RATHER THAN THIS, THE ESTIMATORS HAVE BEEN INCLINED TO USE THE VALUE WHICH WOULD MOST LIKELY OCCUR UNDER THE ASSUMED CIRCUMSTANCES; THAT IS, THE MODAL VALUE OF THE FREQUENCY DISTRIBUTION ASSOCIATED WITH THE ESTIMATE. WHILE THE MODAL VALUE WILL COINCIDE WITH THE EXPECTED VALUE, THE MEAN, IN SYMMETRICAL FREQUENCY DISTRIBUTIONS, AN ASSUMPTION OF SYMMETRY PERTAINING TO THE FREQUENCY DISTRIBUTIONS OF COST AND BENEFIT ESTIMATES WOULD NOT BE ONE IN WHICH A DECISION-MAKER COULD PLACE GREAT CONFIDENCE.[1]

COSTS WOULD SEEM TO ASSUME AN ASYMMETRICAL FREQUENCY DISTRIBUTION RATHER THAN A SYMMETRICAL DISTRIBUTION, FOR ONE COULD LIST MANY FACTORS WHICH MIGHT DRASTICALLY INCREASE

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[1]FREQUENCY DISTRIBUTIONS ASSOCIATED WITH ESTIMATES OF COSTS AND BENEFITS ARE ASSUMED TO BE UNIMODAL.

COSTS, YET FEW FACTORS WHICH WOULD CAUSE COST DECREASES OF THE SAME MAGNITUDE. THIS IS ESPECIALLY TRUE IN LIGHT OF THE RELATIVELY SHORT TIME PERIOD OVER WHICH EXPENDITURES ARE MADE, A TIME PERIOD USUALLY INSUFFICIENT FOR A TECHNICAL BREAKTHROUGH, FOR EXAMPLE, TO INFLUENCE THE INVESTMENT IN ANY APPRECIABLE WAY. HOWEVER, SINCE THE ADVERSITIES WHICH MIGHT CAUSE A RADICAL COST INCREASE WOULD NOT SEEM TO HAVE A HIGH PROBABILITY OF OCCURRENCE, A TYPICAL COST FREQUENCY DISTRIBUTION MIGHT APPEAR AS SHOWN IN ILLUSTRATION 1, PAGE 49. THE DISTRIBUTION SHOWN IN THIS ILLUSTRATION IS SKEWED TO THE RIGHT WITH THE MODE, M_C, TO THE LEFT OF THE MEAN, OR EXPECTED VALUE OF THE DISTRIBUTION, E_C. THE RESULT OF THIS SKEWNESS WOULD BE A PERPETUAL UNDERESTIMATION OF COSTS WHICH WOULD PRODUCE INACCURATE ESTIMATES OF NECESSARY APPROPRIATIONS AND COULD ALSO CONTRIBUTE TO A BIAS IN THE BENEFIT-COST RATIO TOWARD PROJECT JUSTIFICATION. THIS APPARENT CONSISTENCY OF UNDER-ESTIMATION OF COSTS, WHICH HAS ACTUALLY BEEN EXHIBITED IN PAST EXPENDITURE PROPOSALS, WOULD NOT NECESSARILY BE A SIGN OF INCOMPETENCE OR DISHONESTY ON THE PART OF THE ANALYST; RATHER IT COULD BE THE RESULT OF ESTIMATING A MEASURE OF THE DISTRIBUTION OTHER THAN THE EXPECTED VALUE, A CONDITION CONDONED BY THE ERRONEOUS SYMMETRY ASSUMPTION.[1]

THE REVERSE SITUATION COULD HOLD FOR ESTIMATES OF BENEFITS, AND THE BENEFIT DISTRIBUTION COULD BE SKEWED TO THE

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[1]FOR AN ANALYTICAL PROOF APPROPRIATE TO THIS DISCUSSION, SEE GIGUET AND MORLAT (19).

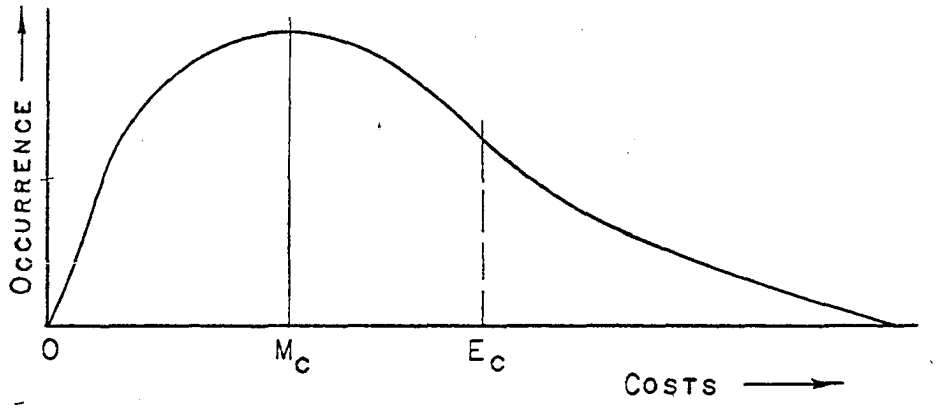

ILLUSTRATION 1. AN ASYMMETRICAL FREQUENCY DISTRIBUTION OF POSSIBLE OUTCOMES OF COST ESTIMATION

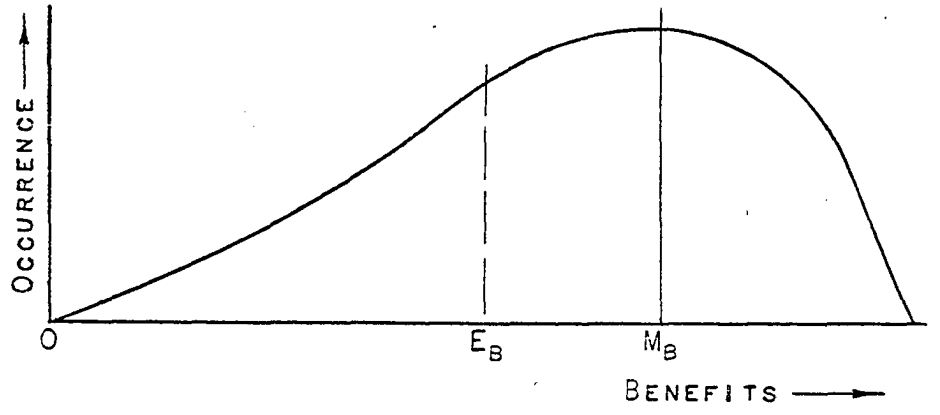

ILLUSTRATION 2. AN ASYMMETRICAL FREQUENCY DISTRIBUTION OF POSSIBLE OUTCOMES OF BENEFIT ESTIMATION

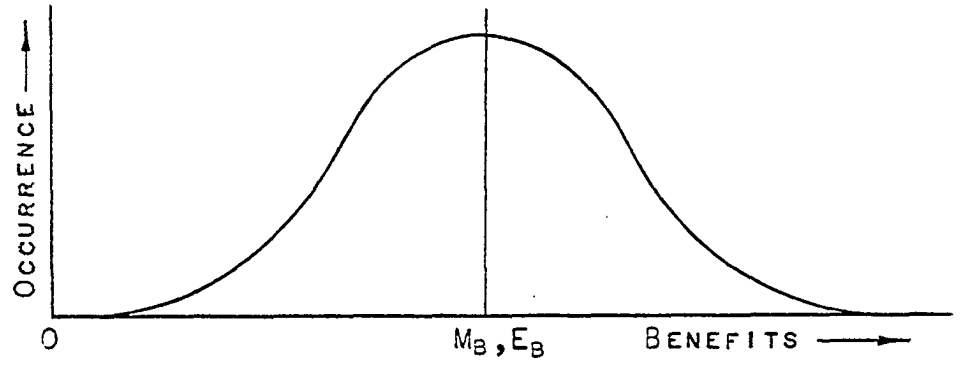

ILLUSTRATION 3. A SUMMETRICAL FREQUENCY DISTRIBUTION OF POSSIBLE OUTCOMES OF BENEFIT ESTIMATION

LEFT, RESULTING IN AN EXPECTED VALUE, E_B, LESS THAN THE MODAL VALUE, M_B, AS SHOWN IN ILLUSTRATION 2, PAGE 49. THE ASYMMETRIC DISTRIBUTION SHOWN IN ILLUSTRATION 2 MAY BE JUSTIFIED THROUGH THE REALIZATION THAT PEOPLE OFTEN HOPE FOR A GREATER RETURN OF BENEFITS FROM AN INVESTMENT THAN ACTUALLY RESULT. HOWEVER, MANY POSSIBLE ADVERSITIES COULD REDUCE THE RETURN OF BENEFITS FROM THE VALUE THOUGHT MOST LIKELY TO OCCUR. NOT ONLY HAVE SUCH ADVERSITIES, CAUSING A REDUCTION IN BENEFITS FROM THE ORIGINAL ESTIMATES, OCCURRED IN THE PAST, BUT IN A FEW CASES, PROJECTS HAVE BEEN ABANDONED COMPLETELY. THUS A SKEWNESS TO THE LEFT OF THE BENEFIT DISTRIBUTION WOULD BE REASONABLE AND SUCH A SKEWNESS WOULD RESULT IN A FACTOR OF OVEROPTIMISM BEING INTRODUCED INTO THE BENEFIT ESTIMATES. THE MAGNITUDE OF THIS OVEROPTIMISM WOULD BE INDICATED BY, AS IN THE CASE OF COSTS, THE DIFFERENCE BETWEEN THE MODE, M_B, AND THE EXPECTED VALUE, E_B. A SKEWED BENEFIT DISTRIBUTION WOULD AGAIN CONTRIBUTE TO FAULTY ESTIMATES AND BIAS IN THE BENEFIT-COST RATIO TOWARDS PROJECT JUSTIFICATION.

ONE MIGHT PRESENT, HOWEVER, A CONVINCING ARGUMENT FOR A SYMMETRICAL DISTRIBUTION OF BENEFITS. THE BENEFITS DERIVED FROM A PROJECT ARE RETURNED TO THE INVESTORS OVER A LONG SPAN OF TIME AND MANY UNFORESEEN CONDITIONS MIGHT INCREASE THE BENEFITS FROM AN INVESTMENT SUFFICIENTLY TO COUNTER ANY POSSIBLE ADVERSITIES. IN A SYMMETRICAL DISTRIBUTION THE MEAN AND MODE WOULD COINCIDE, AS SHOWN IN ILLUSTRATION 3, PAGE 49.

ANOTHER SOURCE OF POSSIBLE ERROR, WHICH MIGHT OCCUR THROUGH THE USE OF MODAL ESTIMATES TAKEN FROM SKEWED DISTRIBUTIONS, COULD ARISE FROM THE AGGREGATION BIAS INTRODUCED INTO THE EXPRESSION BY THE ADDITION OF MODAL VALUES. WHILE THE SUM OF THE EXPECTED VALUES IS EQUAL TO THE EXPECTED VALUE OF THE SUM, THE SUM OF THE MODES DOES NOT NECESSARILY EQUAL THE MODE OF THE SUM.[1] THUS, ANOTHER ELEMENT OF ERROR MAY BE INTRODUCED INTO THE DECISION CRITERION.

THE INFLUENCE OF THE USE OF MODAL VALUES OF SKEWED DISTRIBUTIONS, RESULTING IN COST UNDERESTIMATIONS AND BENEFIT OVERESTIMATIONS, UPON THE BENEFIT-COST RATIO TENDS TO INFLATE THIS RATIO, INCREASING THE LIKELIHOOD OF PROJECT AUTHORIZATION. THIS RESULTING INFLATION OF THE BENEFIT-COST RATIO COULD

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[1] THE READER MAY VERIFY THIS STATEMENT THROUGH AN EXAMPLE. IF ONE WERE TO CONSIDER A GAMMA DISTRIBUTION WHERE

$$F(x_1) \sim \Gamma(\alpha_1, \beta)$$
$$F(x_2) \sim \Gamma(\alpha_2, \beta)$$

AND WHERE THE SUM OF THESE TWO DISTRIBUTIONS WOULD BE

$$F(x_1 + x_2) \sim \Gamma(\alpha_1 + \alpha_2 + 1, \beta),$$

THEN THE MODES OF THESE RESPECTIVE DISTRIBUTIONS WOULD BE

$$M_{x_1}(T) = \frac{1}{(1 - \beta T)^{\alpha_1 + 1}}$$
$$M_{x_2}(T) = \frac{1}{(1 - \beta T)^{\alpha_2 + 1}}$$
$$M_{x_1 + x_2}(T) = \frac{1}{(1 - \beta T)^{(\alpha_1 + \alpha_2 + 1) + 1}}.$$

THUS, IN SUCH A DISTRIBUTION THE SUM OF THE MODES IS NOT EQUAL TO THE MODE OF THE SUMS.

PRODUCE A SITUATION IN WHICH PROJECTS WITH BIASED BENEFIT-COST RATIOS MIGHT BE ACCEPTED TO THE EXCLUSION OF TRULY JUSTIFIED PROJECTS.[1] THIS POINT WILL BE DISCUSSED AGAIN IN THE FOLLOWING CHAPTERS.

IN THE DISCUSSION ON THE USE OF MODAL ESTIMATES, THE EXISTENCE WAS RECOGNIZED OF A FREQUENCY DISTRIBUTION ASSOCIATED WITH THE ESTIMATE OF EACH COMPONENT FACTOR. PAST FAILURES TO RECOGNIZE THE EXISTENCE OF THESE DISTRIBUTIONS MIGHT HAVE LED THE DECISION-MAKERS TO DRAW ERRONEOUS CONCLUSIONS CONCERNING THE DESIRABILITY OF VARIOUS PROPOSALS. THUS, WHILE CONSIDERATION HAS NOT BEEN GIVEN TO BOTH THE EXPECTED VALUE AND THE VARIANCE OF THE DISTRIBUTIONS ASSOCIATED WITH ESTIMATED OUTCOMES IN THE PAST, VALUABLE INFORMATION CONCERNING THE CHARACTERISTICS OF THE POSSIBLE OUTCOMES WOULD BE PROVIDED BY THESE STATISTICS AND THE CONSIDERATION OF THE VARIANCE WOULD SERVE THE FUNCTION OF AN EXPECTED VALUE ADJUSTMENT FACTOR MENTIONED PREVIOUSLY. FOR EXAMPLE, IF A CHOICE WERE TO BE MADE BETWEEN TWO PROPOSED INVESTMENTS, BOTH HAVING IDENTICAL EXPECTED NET RETURNS AND BENEFIT-COST RATIOS, BUT ONE HAVING THE POSSIBILITY OF MUCH GREATER VARIATIONS FROM THE ESTIMATED EXPECTED VALUES THAN THE OTHER, THEN ONLY WITH PERTINENT INFORMATION ON THE

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[1] ONE MIGHT CONCLUDE THAT, WITH THE LOW INTEREST RATE USED IN PROJECT FEASIBILITY STUDIES, THE INCLUSION OF DUBIOUS BENEFITS AND SECONDARY BENEFITS IN THE BENEFIT-COST RATIO, AND THE BUILT-IN FACTORS PRODUCING INFLATED BENEFIT-COST RATIOS, IT WOULD BE DIFFICULT TO CONCEIVE HOW ANY REASONABLE PROJECT FAILS TO PASS A TEST OF FEASIBILITY.

VARIANCES ASSOCIATED WITH THESE EXPECTED VALUES COULD THE DECISION-MAKER ADEQUATELY EVALUATE THE RISKS INVOLVED AND DETERMINE THE PROPER COURSE OF ACTION. HOWEVER, IN EXISTING PROCEDURES USED FOR ECONOMIC ANALYSES, ALL ESTIMATED VALUES ARE CONSIDERED TO BE CERTAIN, AND THEREFORE, NO ALLOWANCES HAVE BEEN MADE FOR POSSIBLE DEVIATIONS FROM EXPECTED VALUES.

IN PASSING, ONE POSSIBLE METHOD OF COMPENSATING FOR DEVIATIONS FROM THE EXPECTED VALUE OF ESTIMATES HAS BEEN PROPOSED BY J. R. HICKS (27), USING WHAT HE HAS REFERRED TO AS CERTAINTY-EQUIVALENTS. CERTAINTY-EQUIVALENTS ARE OF NOTE BECAUSE THEIR USE HAS BEEN ADVOCATED RECENTLY IN ANALYSES OF WATER-RESOURCE PROJECTS (24). MOST OF THE CLASSICAL DISCUSSIONS OF CERTAINTY-EQUIVALENTS HAVE BEEN BASED UPON THE DIFFERENCES IN EXPECTATIONS OF BUYERS AND SELLERS TOWARD FUTURE PRICES. THE HYPOTHESIS HAS BEEN PRESENTED THAT AN EXPECTED PRICE WITHIN AN ENVIRONMENT OF UNCERTAINTY COULD BE REPLACED BY A CERTAIN PRICE, FOUND BY "THE MOST PROBABLE PRICE $\pm$ AN ALLOWANCE FOR THE UNCERTAINTY OF EXPECTATION, THAT IS TO SAY, AN ALLOWANCE FOR RISK."[1] (27, PP. 125-126) THIS COMPENSATION FOR UNCERTAINTY, HOWEVER, TENDS TO MERELY BE AN

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[1]WHEN HE USES THE TERM MOST PROBABLE PRICE, HICKS MIGHT HAVE BEEN IMPLYING THAT ONE SHOULD ADJUST THE MODAL ESTIMATE TO OBTAIN AN APPROXIMATION OF THE EXPECTED VALUE OF A SKEWED DISTRIBUTION. LANGE (39, P. 31) CONCURS ON THE POINT THAT HICKS INTENDED THE CERTAINTY-EQUIVALENT TO BE AN ADJUSTMENT FOR MODAL ESTIMATES. HIRSHLEIFER (28), HOWEVER, MISINTERPRETS THIS ADJUSTMENT AND ASSUMES THAT THE CERTAINTY-EQUIVALENT IS AN ADJUSTMENT FACTOR WHICH SHOULD COMPENSATE FOR DISTRIBUTION SKEWNESS BY VARYING THE EXPECTED VALUE.

ADJUSTMENT TO THE MODAL ESTIMATES SO AS TO APPROXIMATE EXPECTED VALUES AND REDUCE A CAUSE OF CHRONIC MISESTIMATION DISCUSSED PREVIOUSLY. HOWEVER, THE CERTAINTY-EQUIVALENTS STILL PROVIDE NO INDICATION OF THE MAGNITUDE OF THE VARIANCES ASSOCIATED WITH THE ESTIMATED EXPECTED VALUES AND ALSO, ADDITIONAL ERRORS WOULD BE INTRODUCED INTO THE DECISION CRITERION THROUGH THE USE OF A MEASURE OTHER THAN THE EXPECTED VALUE. THUS, THE USE OF CERTAINTY-EQUIVALENTS MUST BE REJECTED FOR THE PURPOSES OF THIS INVESTIGATION.

CONTINGENCY INDEX

ET MALE CONSULTIS PRETIUM EST: PRUDENTIA FALLIT:
NEC FORTUNA PROBAT CAUSAS, SEQUITURQUE MERENTES,
SED VEGA PER CUNCTOS NULLO DISCRIMINE FETUR.[1]

THIS STUDY HAS BEEN CRITICAL OF THE TREATMENT OF UNCERTAINTY IN EXISTING ESTIMATION TECHNIQUES USED IN GOVERNMENTAL CAPITAL EXPENDITURE PROPOSALS BECAUSE NO CONSIDERATION HAS BEEN GIVEN TO THE DISTRIBUTION OF OUTCOMES ASSOCIATED WITH THE ESTIMATED EXPECTED VALUES OF BENEFITS, COSTS, OR THE BENEFIT-COST RATIO. IT WAS STATED THAT INFORMATION ON DEVIATIONS FROM THE ESTIMATED EXPECTED VALUES WOULD BE HELPFUL TO THE DECISION-MAKER IN SELECTING THE PROPOSALS WHICH SHOULD RECEIVE AN APPROPRIATION OF FUNDS.[2] HOWEVER, IN ORDER TO CONTINUE THIS DISCUSSION CONCERNING THE NECESSITY OF RECOGNIZING THE DISTRIBUTION OF POSSIBLE OUTCOMES ASSOCIATED WITH AN ESTIMATED VALUE IN AN UNCERTAIN ENVIRONMENT, THE ACTUAL EXISTENCE OF SUCH A DISTRIBUTION SHOULD BE VERIFIED. IN THIS VERIFICATION THE CHARACTERISTICS OF THE DISTRIBUTIONS, IF, IN FACT, SUCH DISTRIBUTIONS EXIST, MAY ALSO BE DETERMINED.

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[1] THERE MAY BE GOOD IN ILL COUNSEL: PRUDENCE IS DECEITFUL AND UNCERTAIN: FORTUNE DOES NO INQUIRE INTO CAUSES AS A MATTER OF COURSE NOR AID THE MOST DESERVING, BUT TURNS HITHER AND THITHER WITHOUT DISCRIMINATION. MANILUS, IV. 95, ASTRONOMICA, AS QUOTED BY MONTAIGNE (46, P. 139).

[2] IF A SELECTION MUST BE MADE BETWEEN COMPETING PROPOSALS, THEN THE ASSUMPTION OF RATIONED CAPITAL WOULD BE IMPLIED. THE CAPITAL RATIONING ASSUMPTION WOULD SEEM TO BE VALID, FOR IT WOULD BE UNLIKELY THAT A BUDGET WOULD BE SUFFICIENT TO ENCOMPASS ALL POSSIBLE PROJECTS DEMANDING FUNDS AT A PARTICULAR POINT IN TIME.

THESE DISTRIBUTION CHARACTERISTICS, THE MEAN AND VARIANCE, COULD BE HELPFUL TO THE DECISION-MAKER, AS PREVIOUSLY MENTIONED, BY ASSISTING IN A MORE COMPREHENSIVE ALLOCATION OF RATIONED FUNDS. THEREFORE, IN ORDER TO VERIFY THAT A DISTRIBUTION OF OUTCOMES HAS EXISTED IN THE PAST AND TO DEFINE THE CHARACTERISTICS OF SUCH A DISTRIBUTION, AN INDEX WILL BE DEVELOPED IN THIS CHAPTER WHICH WILL PERFORM BOTH OF THESE FUNCTIONS.

DERIVATION OF THE CONTINGENCY INDEX

AN INDEX USED TO MEASURE THE EFFECTIVENESS OF PAST ESTIMATION PERFORMANCE IDEALLY SHOULD MEASURE TWO PROPERTIES ATTRIBUTABLE TO THE ESTIMATED VALUES. THE FIRST, AND MOST IMPORTANT PROPERTY TO BE MEASURED WOULD BE THE ACCURACY OF ESTIMATION. THE SECOND PROPERTY WHICH THE INDEX SHOULD MEASURE WOULD BE THE EFFECT OF MISESTIMATION UPON A PROJECT'S CONTRIBUTION TO THE NATIONAL WELFARE, RELATIVE TO THE ORIGINAL ESTIMATE.

A MEASURE OF THE ACCURACY OF AN ESTIMATE MAY BE FOUND USING THE ACCEPTED DEVIATION EXPRESSION, WHICH, FOR BENEFITS AND COSTS RESPECTIVELY WOULD APPEAR AS:

$$R_B' = \frac{\text{ACTUAL BENEFITS} - \text{ESTIMATED BENEFITS}}{\text{ESTIMATED BENEFITS}}, \qquad (6)$$

$$R_C' = \frac{\text{ACTUAL COSTS} - \text{ESTIMATED COSTS}}{\text{ESTIMATED COSTS}}, \qquad (7)$$

WHERE R_B' = THE DEVIATION OF ACTUAL BENEFITS FROM ESTIMATED BENEFITS, AND

R_C' = THE DEVIATION OF ACTUAL COSTS FROM ESTIMATED

costs.

Equations 6 and 7 may be transformed as follows:

$$R_B' = \frac{\text{Actual Benefits}}{\text{Estimated Benefits}} - 1$$

$$R_C' = \frac{\text{Actual Costs}}{\text{Estimated Costs}} - 1$$

However, the variation shown by a ratio is not appreciably affected by the addition or subtraction of a constant; therefore, disregarding the minus one in the above expression, the deviations of actual costs and benefits from their estimated values would appear as:

$$R_B'' = \frac{\text{Actual Benefits}}{\text{Estimated Benefits}} \qquad (8)$$

$$R_C'' = \frac{\text{Actual Costs}}{\text{Estimated Costs}} . \qquad (9)$$

Equations 8 and 9 would provide a test of estimation accuracy; for, if the estimates of benefits and costs were proven to be accurate, the values of R_B'' and R_C'' would approach one.

While equations 8 and 9 would measure the accuracy of estimation, thus satisfying the first desired function of an index, they would not provide a consistent measure of the relative contribution of a project to the nation's economy when deviations from the estimated values had occurred. A project's contribution to the national economy would be greater than expected, <u>ceteris paribus</u>, if the benefits to be derived from the project had been underestimated. For even though the estimate were incorrect, the error would not have been detrimental to the national welfare. In this case the value

OF R_B'' FROM EQUATION 8 WOULD BE GREATER THAN ONE. AN ERROR MADE THROUGH THE OVERESTIMATION OF COSTS, CETERIS PARIBUS, WOULD LIKEWISE PROVIDE A POSITIVE CONTRIBUTION TO THE NATIONAL WELFARE RELATIVE TO THE ORIGINAL ESTIMATE. HOWEVER, IN THIS INSTANCE THE VALUE OF R_C'' OBTAINED FROM EQUATION 9 WOULD BE LESS THAN ONE. IN ORDER TO REMEDY THIS INCONSISTENCY, EQUATIONS 8 AND 9 WILL BE WRITTEN SO THAT THE EXPRESSION FOR THE DEVIATION OF THE ACTUAL VALUES FROM THEIR ESTIMATES WOULD APPEAR AS:

$$R_B = \frac{\text{ACTUAL BENEFITS}}{\text{ESTIMATED BENEFITS}} \qquad (10)$$

$$R_C = \frac{\text{ESTIMATED COSTS}}{\text{ACTUAL COSTS}} . \qquad (11)$$

EQUATIONS 10 AND 11 WOULD STILL PROVIDE A MEASURE OF ACCURACY, FOR THE ESTIMATES WOULD BE PROVEN TO HAVE BEEN ACCURATE IF THE VALUES OF R_B AND R_C APPROACHED ONE. IN ADDITION EQUATIONS 10 AND 11 ALSO WOULD PROVIDE A CONSISTENT MEASURE OF THE RELATIVE CONTRIBUTION OF A PROJECT TO THE NATIONAL ECONOMY, FOR IF THIS CONTRIBUTION OF THE BENEFIT OR COST COMPONENT WERE GREATER THAN EXPECTED, THE RESPECTIVE VALUES OF R_B AND R_C WOULD BE GREATER THAN ONE. THUS, A TEST WOULD BE AVAILABLE TO DETERMINE HOW WELL THE ESTIMATION PROCESS HAS FUNCTIONED FOR A PARTICULAR COMPONENT OF THE BENEFIT-COST RATIO, AND SUCH A MEASURE COULD BE USED IN CONNECTION WITH AN EFFORT TO REDUCE ESTIMATION INACCURACIES.

WHILE INFORMATION CONCERNING THE INACCURACIES IN THE ESTIMATION OF BENEFITS AND COSTS WOULD BE IMPORTANT, THE

QUESTION WOULD STILL EXIST AS TO THE EFFECT OF THESE INACCURACIES UPON THE DECISION CRITERION, THE BENEFIT-COST RATIO. IT WOULD, THEREFORE, BE DESIRABLE TO OBTAIN A MEASURE OF THE EFFECT OF ESTIMATION INACCURACIES UPON THE BENEFIT-COST RATIO, A MEASURE WHICH WOULD RETAIN A RELATIONSHIP BETWEEN THE DISTRIBUTION OF OUTCOMES OF THE BENEFIT-COST RATIO AND THE DISTRIBUTION OF THE OUTCOMES OF THE INDIVIDUAL COMPONENTS.

IN ADDITION TO SATISFYING THE ABOVE CONDITION, AN INDEX WHICH WOULD BE USED TO MEASURE THE EFFECTIVENESS OF ESTIMATING THE BENEFIT-COST RATIO SHOULD POSSESS TWO OTHER CHARACTERISTICS, CHARACTERISTICS WHICH WOULD ASSIST IN PROVIDING UNBIASED COMPARISONS AMONG PROJECTS. FIRST, THE INDEX SHOULD BE UNITLESS. ALTHOUGH BENEFITS AND COSTS ARE NOW GENERALLY ESTIMATED IN TERMS OF A COMMON UNIT, DOLLARS, THIS USE OF A CONSISTENT UNIT FOR ESTIMATES OF BENEFITS AND COSTS HAS NOT ALWAYS BEEN AN ACCEPTED COMMON PRACTICE. FOR EXAMPLE, BENEFITS ESTIMATED FOR RECLAMATION PROJECTS AUTHORIZED BEFORE 1939 WERE GENERALLY EXPRESSED IN TERMS OF ACRES TO BE IRRIGATED.[1] SECOND, THE INDEX SHOULD NOT BE INFLUENCED BY VARIATIONS IN THE RELATIVE MAGNITUDE OF THE COMPONENTS OF THE BENEFIT-COST RATIO. SENSITIVITY TO VARIATIONS IN MAGNITUDE

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[1]ONE MIGHT ALSO NOTE THAT NO ASSURANCE EXISTS THAT THE BENEFITS DERIVED FROM A PROJECT OR THE FUNDS INVESTED IN A PROJECT ARE REALLY EXPRESSED IN TERMS OF DOLLARS OF THE SAME VALUE. COMPLEX ECONOMIC JUDGMENTS MIGHT HAVE TO BE INTRODUCED INTO AN INDEX WHICH IS EXPRESSED IN SOME TYPE OF UNITS, AND EVEN CORRECTIONS OF POSSIBLE DISCREPANCIES THROUGH THE USE OF COST AND PRICE INDICES STILL MIGHT NOT RENDER THE VALUES OF COSTS AND BENEFITS COMPATIBLE.

AMONG COMPONENTS OR AMONG PROJECTS WOULD SERVE ONLY TO CONFUSE POSSIBLE COMPARISONS.

AS DISCUSSED PREVIOUSLY, THE BENEFIT-COST RATIO, Z, HAS BEEN DEFINED AS:

$$Z = \frac{\Sigma \text{BENEFITS}}{\Sigma \text{COSTS}} .$$

FOR THE PURPOSES OF THIS DISCUSSION, THE COST AND BENEFIT COMPONENTS OF THIS RATIO WILL BE ASSUMED TO BE COMPOSED OF THE SUM OF ALL COSTS AND BENEFITS ASSOCIATED WITH A PROJECT. AN ADDITIONAL ASSUMPTION WILL BE MADE THAT THE INDIVIDUAL ESTIMATES OF COSTS AND BENEFITS WHICH WOULD COMPRISE THE TOTAL COMPONENT VALUES WOULD BE INDEPENDENT QUANTITIES; THUS, THEIR VARIANCES AND MEANS WOULD BE ADDITIVE WITHOUT THE INTRODUCTION OF ADDITIONAL BIAS INTO THE BENEFIT-COST RATIO.

IN ORDER TO DETERMINE THE ESTIMATION ACCURACY OF THE BENEFIT-COST RATIO FOR A PROJECT, ONE COULD ESTABLISH AN EXPRESSION SHOWING THE DIFFERENCE BETWEEN ESTIMATED AND ACTUAL RESULTS, ξ', SUCH AS:

$$\xi' = \frac{\text{ACTUAL BENEFITS}}{\text{ACTUAL COSTS}} - \frac{\text{ESTIMATED BENEFITS}}{\text{ESTIMATED COSTS}} .$$

HOWEVER, THIS EXPRESSION WOULD BE SENSITIVE TO VARIATIONS IN MAGNITUDE AND WOULD ALSO BE AFFECTED BY THE UNITS OF THE COMPONENTS. IN ORDER TO SATISFY THESE OBJECTIONS, THE ABOVE EXPRESSION MAY BE NORMALIZED AS FOLLOWS:

$$\xi = \frac{\dfrac{\text{ACTUAL BENEFITS}}{\text{ACTUAL COSTS}} - \dfrac{\text{ESTIMATED BENEFITS}}{\text{ESTIMATED COSTS}}}{\dfrac{\text{ESTIMATED BENEFITS}}{\text{ESTIMATED COSTS}}} . \qquad (12)$$

THIS NORMALIZED RATIO WOULD BE A UNITLESS EXPRESSION WHICH WOULD SHOW THE DEVIATION BETWEEN THE ACTUAL AND ESTIMATED VALUES OF THE BENEFIT-COST RATIO. THIS EXPRESSION COULD BE TRANSFORMED IN THE FOLLOWING MANNER TO RELATE IT SPECIFICALLY TO THE DEVIATIONS OF THE INDIVIDUAL COMPONENTS.

$$\xi = \frac{\frac{\text{Actual Benefits}}{\text{Actual Costs}}}{\frac{\text{Estimated Benefits}}{\text{Estimated Costs}}} - 1$$

$$\xi = \frac{\text{Actual Benefits}}{\text{Estimated Benefits}} \times \frac{\text{Estimated Costs}}{\text{Actual Costs}} - 1 \qquad (13)$$

SUBSTITUTING EQUATIONS 10 AND 11 INTO EQUATION 13, THE FOLLOWING EXPRESSION WOULD BE OBTAINED.

$$\xi = (R_B)(R_C) - 1 \qquad (14)$$

EQUATION 14 WOULD SEEM TO BE AN APPROPRIATE INDEX FOR MEASURING THE EFFECTIVENESS OF BENEFIT AND COST ESTIMATION, FOR IT IS A SYMMETRICAL RELATIONSHIP WHICH IS UNITLESS, INSENSITIVE TO DIFFERENCES IN RELATIVE MAGNITUDE OF THE COMPONENTS, AND IT APPROACHES ZERO WHEN THE ESTIMATES OF BENEFITS AND COSTS HAVE BEEN ACCURATE.

WHILE EQUATION 14 WOULD BE AN APPROPRIATE MEASURE OF ESTIMATION PERFORMANCE FOR ANALYZING PROJECTS AFTER THEIR COMPLETION, DIFFICULTIES MIGHT ARISE IF ξ WERE USED TO DETERMINE THE POSSIBLE EFFECTS OF UNCERTAIN OUTCOMES OF BENEFITS AND COSTS UPON THE BENEFIT-COST RATIO. REFERRING TO THE ASSUMPTION OF INDEPENDENCE OF ESTIMATED QUANTITIES, THE ANALYSIS OF THE EFFECT OF THE DISTRIBUTION OF COMPONENT OUT-

COMES UPON THE DISTRIBUTION OF POSSIBLE BENEFIT-COST RATIOS WOULD BE SIMPLIFIED IF THE FACTORS WERE ADDITIVE RATHER THAN MULTIPLICATIVE. THE SIMPLIFIED ANALYSIS WOULD RESULT FROM THE PREVIOUSLY MENTIONED FACT THAT, FOR INDEPENDENT QUANTITIES, THE EXPECTED VALUES AND THE VARIANCES OF THESE FACTORS MAY BE SUMMED WITHOUT INTRODUCING ADDITIONAL BIAS INTO THE EXPRESSION. THUS, ONE COULD PREDICT THE RELATIVE AFFECT OF THE MISESTIMATION OF BENEFITS OR COSTS UPON THE FINAL BENEFIT-COST RATIO BY SUMMING THE EXPECTED VALUES AND THE VARIANCES OF THESE COMPONENTS TO OBTAIN THE EXPECTED VALUE AND THE VARIANCE OF THE BENEFIT-COST RATIO DISTRIBUTION. AN INDEX COMPOSED OF ADDITIVE FACTORS WILL BE OBTAINED BY THE FOLLOWING TRANSFORMATION.

IF ONE WERE TO TAKE THE LOGARITHM OF BOTH SIDES OF EQUATION 14, ONE WOULD FIND THE NEW EXPRESSION TO BE:

$$\rho_{BC} = \rho_B + \rho_C, \tag{15}$$

WHERE $$\rho_B = \mathrm{LN}(R_B) \tag{16}$$

$$\rho_C = \mathrm{LN}(R_C) . \tag{17}$$

THE RESULTING EXPRESSION YIELDS A VALUE, ρ_{BC}, WHICH WILL BE REFERRED TO IN THIS STUDY AS THE CONTINGENCY INDEX.[1] EQUATION

[1] THE INDEX DERIVED IN EQUATION 15 WAS NAMED THE CONTINGENCY INDEX BECAUSE A CONTINGENCY MAY BE DEFINED AS A POSSIBLE, OR NOT UNLIKELY, EVENT OR CONDITION. SINCE A PREDICTED VALUE OF A BENEFIT-COST RATIO SHOULD BE MERELY THE EXPECTED VALUE OF THE DISTRIBUTION OF ALL POSSIBLE BENEFIT-COST RATIOS WHICH COULD RESULT FROM THAT PARTICULAR SET OF CONDITIONS, A DEVIATION FROM THIS PREDICTED VALUE OF THE BENEFIT-COST RATIO WOULD CERTAINLY NOT BE AN UNLIKELY EVENT; THEREFORE, THE NAME CONTINGENCY INDEX SEEMED APPROPRIATE.

15 PROVIDES AN ADDITIVE, SYMMETRICAL RELATIONSHIP WHICH INTEGRATES THE DISTRIBUTIONS OF THE COMPONENT FACTORS INTO THE DISTRIBUTION OF THE DECISION CRITERION, THE BENEFIT-COST RATIO. SUBSEQUENT DISCUSSION WILL ILLUSTRATE THAT EQUATION 15, COUPLED WITH EQUATIONS 10 AND 11 PROVIDE TOOLS FOR ANALYZING PAST ESTIMATION PERFORMANCE AS WELL AS PREDICTING POSSIBLE AFFECTS UPON THE BENEFIT-COST RATIO FROM MISESTIMATION OF THE BENEFIT AND COST COMPONENTS.

IN ADDITION TO THE DESIRED CHARACTERISTICS OF BEING UNITLESS AND INSENSITIVE TO VARIATIONS IN COMPONENT MAGNITUDE, THE INDEX MUST PROVIDE A MEASURE OF ACCURACY. THE ACCURACY OF THE COST AND BENEFIT ESTIMATES IS INDICATED WHEN THE VALUE OF EQUATIONS 11 AND 10 RESPECTIVELY APPROACH ONE. THUS, ACCURACY IN ESTIMATION OF THE BENEFIT-COST RATIO IS EXHIBITED WHEN EQUATION 14 APPROACHES ZERO.[1]

THE EFFECT OF MISESTIMATION UPON A PROJECT'S CONTRIBUTION TO THE NATIONAL WELFARE, RELATIVE TO THE ORIGINAL ESTIMATE, WAS THE SECOND PROPERTY WHICH THE INDEX SHOULD MEASURE. AS

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[1]THE DISCERNING READER MAY HAVE NOTICED AT THIS POINT THAT WHILE ρ_{BC} WOULD APPROACH ZERO WHEN COSTS AND BENEFITS WERE ESTIMATED ACCURATELY, THAT IS, WHEN R_C AND R_B APPROACH ONE, ρ_{BC} COULD ALSO APPROACH ZERO UNDER CONDITIONS OF GROSS MISESTIMATION OF THE INDIVIDUAL COMPONENTS. IF BOTH COSTS AND BENEFITS WERE MISESTIMATED IN AN OPPOSITE MANNER BY THE SAME FACTOR, FOR EXAMPLE, 100, ρ_{BC} WOULD STILL EQUAL ZERO. THIS RESULT IS CORRECT, FOR ONE MAY EASILY SHOW THAT SUCH A CASE OF MISESTIMATION WOULD STILL PROVIDE THE SAME BENEFIT-COST RATIO FOR THE ACTUAL RESULT AS FOR THE ORIGINAL ESTIMATE; THEREFORE, THE BENEFIT-COST RATIO WAS ACCURATELY ESTIMATED. THUS, THE PRUDENT ANALYST WOULD PROBABLY UTILIZE EQUATIONS 10, 11, AND 15 FOR A THOROUGH STUDY OF ESTIMATION ACCURACY.

STATED PREVIOUSLY, A GREATER THAN ANTICIPATED CONTRIBUTION WAS MADE TO THE NATION'S ECONOMY IF THE VALUES OF R_B AND R_C FOUND IN EQUATIONS 10 AND 11 RESPECTIVELY WERE GREATER THAN ONE, ALL OTHER THINGS BEING EQUAL. IN LIKE MANNER THEN, THE SAME CONDITION WOULD BE INDICATED BY A POSITIVE VALUE OF ρ_B AND ρ_C IN EQUATIONS 16 AND 17. HOWEVER, THE FINAL TEST OF THE INDEX WOULD NOT BE THE MEASURE OF THE EFFECT UPON THE NATIONAL ECONOMY OF VARIATIONS OF THE INDIVIDUAL COMPONENTS; RATHER, THE FINAL TEST OF THE INDEX WOULD BE THE ABILITY TO DETERMINE FROM THE INDEX THE NET EFFECT UPON THE ECONOMY OF COMBINATIONS OF VARIATIONS OF THE INDIVIDUAL COMPONENTS, THAT IS, THE EFFECT UPON THE ECONOMY OF VARIATIONS OF THE BENEFIT-COST RATIO. A GREATER THAN ANTICIPATED CONTRIBUTION HAS ACCRUED TO THE NATION WHENEVER THE VALUE FOR ρ_{BC} FROM EQUATION 15 WAS POSITIVE; THEREFORE, THE CONTINGENCY INDEX SATISFIES ALL OF THE ORIGINALLY STATED CONDITIONS.

EXPANSION OF THE CONTINGENCY INDEX

REFERENCE WAS MADE IN THIS CHAPTER TO THE POSSIBLE EXISTENCE OF DEVIATIONS FROM THE ESTIMATED VALUES OF BENEFITS AND COSTS USED BY NONPROFIT ORGANIZATIONS TO JUSTIFY CAPITAL EXPENDITURES. IN ORDER TO PROVE THE EXISTENCE OF SUCH DEVIATIONS, THE CONTINGENCY INDEX COULD BE UTILIZED TO TEST A SAMPLE OF PROJECTS ACTUALLY CONSTRUCTED, COMPARING THE ORIGINAL ESTIMATES OF COSTS, BENEFITS, AND THE BENEFIT-COST RATIO TO THE ACTUAL RESULTS OBSERVED FOR THOSE PROJECTS COMPRISING THE SAMPLE. SINCE A CONTINGENCY INDEX OF ZERO FOR

A PARTICULAR PROJECT WOULD REPRESENT AN ACCURATE ESTIMATE, THAT IS, THAT NO DEVIATION FROM THE ESTIMATED VALUE HAD BEEN EVIDENT, A VALUE OTHER THAN ZERO FOR THE EXPECTED VALUE OF A SET OF THE CONTINGENCY INDICES OF ALL OF THE PROJECTS COMPRISING THE SAMPLE WOULD INDICATE THE EXISTENCE OF DEVIATIONS FROM THE ESTIMATED VALUES IN PREVIOUS ANALYSES. THE OBSERVED CONTINGENCY INDEX, I, WOULD THEN BE THE EXPECTED VALUE OF THE CONTINGENCY INDICES OF ALL PROJECTS WITHIN A PARTICULAR SAMPLE AND WOULD BE FORMULATED AS FOLLOWS:

$$I_B = E[\rho_B] \tag{18}$$

$$I_C = E[\rho_C] \tag{19}$$

$$I_{BC} = E[\rho_{BC}] \tag{20}$$

HOWEVER, SINCE $\rho_{BC} = \rho_B + \rho_C$, ONE MAY CONCLUDE THAT

$$I_{BC} = I_B + I_C . \tag{21}$$

IF THE EXPECTED VALUES OF ρ_B, ρ_C, AND ρ_{BC} IN EQUATIONS 18, 19, OR 20, RESPECTIVELY, WERE ZERO; THAT IS, IF THE ESTIMATES WERE ACCURATE, THEN THE PROBABILITY DISTRIBUTIONS COULD BE DESCRIBED BY THE MEAN SQUARE DEVIATION FROM ZERO, WHICH WOULD APPEAR AS:

$$J_B = E[\rho_B^2]$$

$$J_C = E[\rho_C^2]$$

$$J_{BC} = E[\rho_{BC}^2],$$

WHERE $E[\rho_{BC}^2] = E[(\rho_B + \rho_C)^2]$

$$= E[\rho_B^2] + E[\rho_C^2] + 2\,E[\rho_B\,\rho_C] .$$

THUS, THE EXPRESSION FOR J_{BC} WOULD BE

$$J_{BC} = J_B + J_C + 2\,E[\rho_B\,\rho_C] .$$

FURTHERMORE, IF ρ_B AND ρ_C WERE UNCORRELATED, THEN

$$J_{BC} = J_B + J_C + 2\, E[\rho_B]\, E[\rho_C],$$

$$J_{BC} = J_B + J_C + 2\, I_B\, I_C,$$

AND, IF EITHER I_B, $I_C = 0$, THEN

$$J_{BC} = J_B + J_C .$$

THEOREM:

IF ρ_B AND ρ_C ARE UNCORRELATED, AND EITHER I_B OR I_C OR I_B AND I_C ARE EQUAL TO ZERO, THEN $J_{BC} = J_B + J_C$.

WHILE THE USE OF THE MEAN SQUARE DEVIATIONS FROM ZERO WOULD SIMPLIFY THE COMPUTATIONAL PROCEDURES, IT WOULD BE UNLIKELY THAT AN OCCASION WOULD ARISE WHEN THEIR USE WOULD BE APPROPRIATE, THAT IS, WHEN THE EXPECTED VALUES OF THE OBSERVED CONTINGENCY INDICES WOULD BE ZERO.

> TO ASSUME THE BENEFIT AND COST ESTIMATES ARE ACCURATE IS AN ASSUMPTION OF DOUBTFUL QUALITY (SEE ECKSTEIN (15) CHAPTERS 5-8). TO SIMPLY ASSUME THAT THESE ESTIMATES ARE ACCURATE, COVERS UP A HOST OF NECESSARY ASSUMPTIONS MADE IN CALCULATING THE ESTIMATED VALUES; ASSUMPTIONS CONCERNING PRICE PROJECTIONS, POPULATION GROWTH, FUTURE LAND USE AND VALUE, FUTURE RIVER TONNAGE AND FUTURE DEMAND FOR POWER TO MENTION A FEW. (24, P. 14)

THEREFORE, IN ORDER TO DESCRIBE THE DISTRIBUTION ASSOCIATED WITH THE DEVIATIONS FROM THE ESTIMATED VALUES, THE VARIANCE OF THE DISTRIBUTION HAS BEEN USED. THESE VARIANCES, TO BE KNOWN AS THE ACCURACY INDICES, J, WOULD BE:

$$J_B = E[\rho_B^2] - (E[\rho_B])^2 \qquad (22)$$

$$J_C = E[\rho_C^2] - (E[\rho_C])^2 \qquad (23)$$

$$J_{BC} = E\left[(\rho_B + \rho_C) - E(\rho_B + \rho_C)\right]^2$$

$$J_{BC} = E\left[\rho_B - E[\rho_B]\right]^2 + E\left[\rho_C - E[\rho_C]\right]^2 + 2\,E\left[\left[\rho_B - E[\rho_B]\right]\left[\rho_C - E[\rho_C]\right]\right]$$

$$= E\left[\rho_B^2\right] - (E[\rho_B])^2 + E\left[\rho_C^2\right] - (E[\rho_C])^2 + 2\,E\left[\rho_B\,\rho_C\right] - 2\,(E[\rho_B]\,E[\rho_C])$$

$$J_{BC} = J_B + J_C + 2\rho\sqrt{(J_B)(J_C)} \qquad (24)$$

WHERE ρ IS THE CORRELATION COEFFICIENT.

AGAIN, IF ρ_B AND ρ_C WERE NOT CORRELATED, THEN

$$J_{BC} = J_B + J_C \,. \qquad (25)$$

THEOREM:

IF ρ_B AND ρ_C ARE UNCORRELATED, THEN $J_{BC} = J_B + J_C$.

> THE MOST IMPORTANT TESTS ARE ALL EMBRACED UNDER THE SINGLE HEAD, FAIRNESS. THE FUNDAMENTAL PURPOSE OF AN INDEX...IS THAT IT SHALL FAIRLY REPRESENT, SO FAR AS ONE SINGLE FIGURE CAN, THE GENERAL TREND OF THE MANY DIVERGING RATIOS FROM WHICH IT IS CALCULATED. IT SHOULD BE A "JUST COMPROMISE" AMONG CONFLICTING ELEMENTS... (17, P. 10)

WITH THE CHARACTERISTICS IMPARTED TO THE CONTINGENCY INDEX, THIS INDEX SHOULD NOT ONLY PROVE TO BE A USEFUL MEASURE OF DEVIATION FROM ESTIMATED VALUES, BUT IT WOULD ALSO SEEM TO MEET FISHER'S TEST OF FAIRNESS; THEREFORE, THE CONTINGENCY INDEX WILL BE USED IN THE ANALYSIS OF PAST ESTIMATION PERFORMANCE.

ESTIMATION RECORD

THE MOVING FINGER WRITES; AND, HAVING WRIT
MOVES ON: NOR ALL THY PIETY NOR WIT
SHALL LURE IT BACK TO CANCEL HALF A LINE,
NOR ALL THE TEARS WASH OUT A WORD OF IT. (52, P. 207)

APPLICATION OF THE CONTINGENCY INDEX

THE CONTINGENCY INDEX WAS TO MEASURE POSSIBLE DEVIATIONS FROM ESTIMATED VALUES OF BENEFITS AND COSTS WHICH MIGHT HAVE OCCURRED IN PREVIOUS CAPITAL EXPENDITURES AND TO DETERMINE THE CHARACTERISTICS OF THE DISTRIBUTION OF THESE DEVIATIONS WHEN THEIR EXISTENCE WAS VERIFIED. IN ADDITION THE CONTINGENCY INDEX WAS TO DETERMINE THE EFFECT UPON THE BENEFIT-COST RATIO OF DEVIATIONS FROM THE ESTIMATED VALUES OF THE COST AND BENEFIT COMPONENTS. THEREFORE, THE CONTINGENCY INDEX SHOULD PROVIDE A MEANS OF LINKING THE CHARACTERISTICS OF PAST ESTIMATION PERFORMANCES TO FUTURE DECISIONS CONCERNING THE ALLOCATION OF CAPITAL AMONG PROPOSED GOVERNMENTAL INVESTMENTS.

A DESCRIPTION OF THE PROCEDURE AN ANALYST MIGHT USE TO DETERMINE THE DISTRIBUTION ASSOCIATED WITH PAST ESTIMATES AND AN OUTLINE OF A SUGGESTED PROCEDURE WHICH WOULD ALLOW INFERENCES TO BE MADE FROM THIS DISTRIBUTION ON ESTIMATES USED IN INVESTMENT PROPOSALS HAS BEEN PRESENTED IN TABLE 3, PAGE 69. THE SUGGESTED PROCEDURE SHOULD PROVIDE A USEFUL TOOL WITH WHICH TO OBTAIN INFORMATION ON THE CHARACTERISTICS OF THE DISTRIBUTION OF POSSIBLE OUTCOMES WITH A MINIMUM OF EFFORT AND COST WHILE STILL MAINTAINING A REASONABLE RELIABILITY IN THE

TABLE 3. A SUGGESTED PROCEDURE FOR APPLYING THE CONTINGENCY INDEX TO THE DETERMINATION OF THE MEAN AND VARIANCE OF A DISTRIBUTION OF POSSIBLE OUTCOMES OF AN ESTIMATED BENEFIT-COST RATIO

1. SELECT A REPRESENTATIVE SAMPLE OF PREVIOUS EXPENDITURES.
2. DETERMINE ESTIMATED VALUES FOR PREVIOUS EXPENDITURES OF:
   A. BENEFITS,
   B. COSTS,
   C. BENEFIT-COST RATIO.
3. DETERMINE THE ACTUAL OUTCOMES OF PREVIOUS CAPITAL INVESTMENTS OF:
   A. BENEFITS,
   B. COSTS,
   C. BENEFIT-COST RATIO.
4. CONVERT THE ACTUAL OUTCOMES TO COMPATIBLE UNITS BY THE:
   A. REDUCTION OF THE ACTUAL AND ESTIMATED VALUES TO A COMMON UNIT OF VALUE,
   B. REDUCTION OF THE ACTUAL AND ESTIMATED VALUES TO A COMMON POINT IN TIME.
5. CALCULATE THE VALUE OF THE VARIOUS INDICES FOR ALL OF THE ELEMENTS IN THE SAMPLE:
   A. BENEFIT CONTINGENCY INDEX, ρ_B,
   B. COST CONTINGENCY INDEX, ρ_C,
   C. CONTINGENCY INDEX, ρ_{BC}
   D. OBSERVED BENEFIT CONTINGENCY INDEX, I_B,
   E. OBSERVED COST CONTINGENCY INDEX, I_C,
   F. OBSERVED CONTINGENCY INDEX, I_{BC},
   G. BENEFIT ACCURACY INDEX, J_B,
   H. COST ACCURACY INDEX, J_C,
   I. ACCURACY INDEX, J_{BC}.
6. PLOT THE FREQUENCY DISTRIBUTION OF CONTINGENCY INDEX.
7. REMOVE ANY CONSISTENT ESTIMATION BIAS FROM THE BENEFIT-COST RATIO ESTIMATION FOR A PROPOSED EXPENDITURE BY ADJUSTING THE ESTIMATED VALUE OF THE BENEFIT-COST RATIO WITH THE OBSERVED CONTINGENCY INDEX FOUND FOR THE SAMPLE OF PREVIOUS EXPENDITURES.
8. ESTABLISH A CONFIDENCE INTERVAL FROM THE ACCURACY INDEX FOUND FOR THE SAMPLE OF PREVIOUS EXPENDITURES.
9. APPLY THIS CONFIDENCE INTERVAL TO THE VALUE OF THE BENEFIT-COST RATIO ESTIMATED OF THE PROPOSED EXPENDITURE.

END RESULT. THUS, THE USE OF THE CONTINGENCY INDEX IN THE MANNER PERSCRIBED IN TABLE 3 WOULD PROVIDE THE DECISION-MAKER WITH AN UNBIASED ESTIMATE OF THE BENEFIT-COST RATIO, PLUS A CONFIDENCE INTERVAL ASSOCIATED WITH THIS UNBIASED ESTIMATE.[1] THE CONTINGENCY INDEX WOULD THEN PROVIDE ONE METHOD OF RECOGNIZING THE DISTRIBUTION OF POSSIBLE OUTCOMES ASSOCIATED WITH AN ESTIMATE OF A BENEFIT-COST RATIO.

A MORE DETAILED EXPLANATION OF THE VARIOUS STEPS IN THE PROCEDURE SHOWN IN TABLE 3 HAS BEEN INCORPORATED INTO THE DEMONSTRATION OF THIS METHOD ON A TYPICAL SAMPLE OF DATA OF GOVERNMENTAL CAPITAL EXPENDITURES FOUND IN THE NEXT SECTION. THIS DEMONSTRATION WILL NOT ONLY ILLUSTRATE THE OPERATION OF THE CONTINGENCY INDEX, BUT ALSO WILL DEMONSTRATE THAT DEVIATIONS FROM ESTIMATED VALUES HAVE ACTUALLY OCCURRED IN THE PAST.

DESCRIPTION OF THE SAMPLE

IN ORDER TO STUDY THE VARIATIONS IN OUTCOMES EXHIBITED BY ESTIMATES OF BENEFITS AND COSTS MADE DURING THE JUSTIFICATION OF GOVERNMENTAL CAPITAL EXPENDITURES, IT WAS NECESSARY TO SELECT SOME SAMPLE OF EXPENDITURES FOR ANALYSIS. A GROUP OF PROJECTS CONSTRUCTED BY THE BUREAU OF RECLAMATION WAS CHOSEN FOR ANALYSIS, DUE PARTLY TO THE AUTHOR'S INTEREST IN THE

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[1] THE TERM CONFIDENCE INTERVAL REFERS TO A RANGE OF VALUES ABOUT WHICH ONE COULD EXPRESS A DEGREE OF CERTAINTY THAT A PARTICULAR OUTCOME WOULD FALL WITHIN THIS RANGE. FOR EXAMPLE, ONE MIGHT BE NINETY-FIVE PER CENT CERTAIN THAT A GIVEN RESULT WOULD FALL WITHIN THE RANGE OF 0.5 TO 1.7.

RECLAMATION PROGRAM, PARTLY TO THE REPRESENTATIVE NATURE OF THIS PROGRAM, AND PARTLY TO THE AVAILABILITY OF PERTINENT DATA. THE PROJECTS CHOSEN FOR ANALYSIS WERE THOSE ORIGINALLY AUTHORIZED PRIOR TO 1939. ONE REASON FOR LIMITING THIS ANALYSIS TO PROJECTS AUTHORIZED BEFORE 1939 WAS THE DESIRE TO SECURE DATA FROM MATURE INVESTMENTS WHICH HAD ACHIEVED A RELATIVELY STABLE LEVEL OF DEVELOPMENT. THE BUREAU OF RECLAMATION ESTIMATES THAT TEN YEARS IS REQUIRED TO DEVELOP AN IRRIGATION PROJECT TO THE POINT OF FULL PRODUCTION. AFTER FULL IRRIGATION DEVELOPMENT HAS BEEN ACHIEVED, SEVERAL YEARS OF CROP PRODUCTION RECORDS HAVE BEEN REQUIRED TO GAIN ASSURANCE THAT A STABLE LEVEL OF DEVELOPMENT HAD BEEN REACHED. SINCE THE LATEST YEAR FOR WHICH DATA WERE AVAILABLE WAS 1962, AN AUTHORIZATION DATE PRIOR TO 1939 WOULD NOT BE AN UNREASONABLE LIMITATION, ESPECIALLY SINCE WORLD WAR II DELAYED THE START OF THE DEVELOPMENT OF SEVERAL PROJECTS UNTIL 1946. IN ADDITION TO THE DESIRE TO INCLUDE ONLY MATURE PROJECTS IN THE ANALYSIS, VARIOUS RECLAMATION ACTS HAVE EXPANDED THE ALLOWABLE SCOPE OF BENEFITS WHICH A RECLAMATION PROJECT MAY CLAIM, SO THAT THE 1939 LIMITATION WAS ALSO IMPOSED AS A CONCESSION TO COMPARATIVE CONSISTENCY.[1]

AFTER IMPOSING THE 1939 LIMITATION UPON THE RECLAMATION

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[1]THE RECLAMATION ACT OF 1939 ALLOWED PROPOSED PROJECTS TO CLAIM BENEFITS FROM FLOOD CONTROL, NAVIGATION, MUNICIPAL WATER SUPPLY AND INDIRECT BENEFITS, AS WELL AS THE CUSTOMARY BENEFITS DERIVED FROM IRRIGATION AND POWER GENERATION. THE RECLAMATION ACT OF 1946 ADDED BENEFITS DERIVED FROM RECREATIONAL USES AND FISH AND WILDLIFE TO THIS LIST.

PROJECTS, FIFTY-SIX PROJECTS REMAINED. OF THESE FIFTY-SIX PROJECTS, SIX PROJECTS HAD BEEN ABANDONED FOR VARIOUS REASONS. THESE PROJECTS WERE ELIMINATED FROM THE SAMPLE. IN ADDITION, TWO OTHER PROJECTS, YUMA AND YUMA AUXILIARY, WERE ELIMINATED BECAUSE THEIR ORIGINAL ESTIMATES WERE COMBINED AND AN APPROPRIATE DIVISION OF THE ESTIMATES WAS NOT POSSIBLE. THE REMAINING FORTY-EIGHT PROJECTS WERE USED AS A SAMPLE FOR THIS ANALYSIS. THESE PROJECTS HAVE BEEN LISTED IN TABLE 4, PAGE 73. THIS SAMPLE INCLUDED AS MANY PROJECTS OF THE ENTIRE POPULATION AS POSSIBLE SO THAT ANY ERRORS INTRODUCED INTO THE ANALYSIS FROM SAMPLING WOULD BE AS SMALL AS POSSIBLE.

EXPLANATION OF THE DATA USED IN THE ANALYSIS

THE DATA USED IN THIS ANALYSIS WERE OBTAINED FROM THE ACTS, CORRESPONDENCE, AND DOCUMENTS PERTAINING TO THE AUTHORIZATION OF THESE PROJECTS, AND FROM THE RECORDS AND PUBLICATIONS OF THE BUREAU OF RECLAMATION. REFERRAL TO THE AUTHORIZATION DOCUMENTS WAS NECESSITATED BY SEVERAL DISCREPANCIES FOUND IN SECONDARY SOURCES OF INFORMATION, SUCH AS THE HOOVER REPORT (98, P. 660).[1]

EVEN THOUGH PRIMARY SOURCES OF DATA WERE EXAMINED, THE ESTIMATES OF BENEFITS AND COSTS USED IN THE JUSTIFICATION OF THE PROJECTS IN THIS SAMPLE WERE NOT VERY EXTENSIVE. ONE REASON FOR THIS LACK OF ESTIMATES WAS THAT SUCH ESTIMATES WERE NOT REQUIRED IN THE JUSTIFICATION OF PROPOSED RECLAMATION

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[1] A LIST OF SOURCES FOR THESE DATA MAY BE FOUND IN THE LITERATURE CITED.

TABLE 4. SELECTED DATA FROM RECLAMATION PROJECTS AUTHORIZED PRIOR TO 1939

PROJECT	YEAR OF INITIAL AUTHORIZATION	TOTAL ESTIMATED ACREAGE TO BE IRRIGATED	IRRIGATED ACREAGE 1953-1962 AVERAGE	AUTHORIZED CONSTRUCTION COST ESTIMATE	TOTAL ADDITIONAL AUTHORIZED CONSTRUCTION COST ESTIMATES	TOTAL COST OF PLANT, PROPERTY AND EQUIPMENT THROUGH 1963
ALL-AMERICAN CANAL	1928	1,000,000	509,080	$38,500,000	$18,100,000	$60,669,835
BAKER	1931	7,400	7,279	200,000	--	225,015
BELLE FOURCHE	1904	60,000	53,867	2,100,000	--	5,027,820
BITTER ROOT	1930	18,630	16,259	750,000	--	1,339,462
BOISE	1905	372,000	324,991	11,000,000	28,050,000	65,733,758
BUFFALO RAPIDS	1937	31,600	21,879	1,605,000	2,070,000	5,016,306
BURNT RIVER	1935	15,000	15,352	550,000	--	601,026
CARLSBAD	1905	25,055	19,727	605,000	2,500,000	5,226,984
CENTRAL VALLEY	1935[A]	1,425,000	710,444	384,314,000	445,973,730	822,999,170
COLORADO-BIG THOMPSON	1937	615,000	678,000	43,883,020	1,530,000	163,257,680
COLUMBIA BASIN	1935[B]	1,200,000	215,437	487,030,000	16,350,000	553,624,720
DESCHUTES	1937	50,000	92,180	8,000,000	1,600,000	12,975,658
FRENCHTOWN	1935	7,000	3,775	220,000	--	279,321
FRUITGROWERS DAM	1938	2,050	1,910	200,000	--	200,000
GILA	1937[C]	115,000	64,412	51,719,040	--	54,815,740
GRAND VALLEY	1911	60,000	35,840	3,621,660	--	6,753,243
HUMBOLDT	1935	40,000	26,238	2,000,000	--	1,337,319
HUNTLEY	1905	35,000	24,199	900,000	--	1,867,514
HYRUM	1935	12,000	5,872	932,000	--	953,853
KENDRICK	1935	66,000	16,547	23,700,000	6,377,000	31,282,325
KLAMATH	1905	236,401	195,429	4,400,000	6,131,600	17,981,059
LOWER YELLOWSTONE	1904	40,000	47,807	1,200,000	--	3,585,927
MILK RIVER	1903	127,200	81,508	1,250,000	2,060,000	9,722,605
MINIDOKA	1904	293,650	1,050,239	2,600,000	102,796,000	37,721,578
MOON LAKE	1935	65,000	54,601	1,500,000	--	1,799,859
NEWLANDS	1903	140,000	55,004	1,250,000	--	7,835,041
NORTH PLATTE	1903	446,000	315,136	400,000	9,016,000	25,369,345
OGDEN RIVER	1935	20,500	15,839	3,500,000	--	5,394,933
OKANOGAN	1905	8,500	3,974	444,000	--	1,495,638
ORLAND	1907	14,000	17,270	650,000	--	3,111,177
OWYHEE	1926	128,300	101,608	17,715,000	1,005,000	19,410,109
PINE RIVER	1938	55,000	35,170	3,240,000	--	3,469,754
PROVO RIVER	1938	85,000	38,957	9,974,000	7,200,000	36,609,362
RIO GRANDE	1905	155,000	42,350	2,317,110	8,905,400	30,135,059
RIVERTON	1920	100,000	52,669	6,777,020	--	24,694,455
SALT RIVER	1903	200,000	245,459	2,800,000	--	20,144,103
SANPETE	1935	12,750	11,891	375,000	--	433,941
SHOSHONE	1904	90,000	76,392	7,171,810	900,000	22,844,136
STRAWBERRY VALLEY	1905	50,000	40,326	1,250,000	--	3,485,421
SUN RIVER	1906	276,000	68,542	9,597,450	--	10,280,007
TRUCKEE STORAGE	1935	30,000	21,718	1,000,000	--	1,092,424
TUCUMCARI	1937	45,000	33,158	8,155,000	--	15,826,077
UMATILLA	1905	20,000	24,150	1,000,000	--	5,152,251
UNCOMPAHGRE	1903	100,000	66,970	2,500,000	--	9,694,698
VALE	1926	32,000	30,955	3,590,000	--	7,706,416
W. C. AUSTIN	1938[D]	70,000	41,320	5,600,000	--	12,247,715
WEBER RIVER	1927	80,000	90,879	3,000,000	--	2,723,485
YAKIMA	1905	433,682	389,855	10,000,000	25,736,000	62,958,334

[A]REAUTHORIZED IN 1946.

[B]REAUTHORIZED IN 1943.

[C]REAUTHORIZED IN 1947.

[D]REAUTHORIZED IN 1941.

EXPENDITURES. SECTION 2 OF THE RECLAMATION ACT OF 1902 STATES

> [T]HAT THE SECRETARY OF THE INTERIOR IS HEREBY AUTHORIZED AND DIRECTED TO MAKE EXAMINATIONS AND SURVEYS FOR, AND TO LOCATE AND CONSTRUCT, AS HEREIN PROVIDED, IRRIGATION WORKS FOR THE STORAGE, DIVERSION, AND DEVELOPMENT OF WATERS, INCLUDING ARTESIAN WELLS, AND TO REPORT TO CONGRESS AT THE BEGINNING OF EACH REGULAR SESSION AS TO THE RESULTS OF SUCH EXAMINATIONS AND SURVEYS, GIVING ESTIMATES OF COSTS OF ALL CONTEMPLATED WORKS, THE QUANTITY AND LOCATION OF THE LANDS WHICH CAN BE IRRIGATED THEREFROM, AND ALL FACTS RELATIVE TO THE PRACTICABILITY OF EACH IRRIGATION PROJECT... (69, P. 61)

THUS THE AVAILABLE DATA WHICH WOULD BE PERTINENT TO ESTIMATES OF COSTS AND BENEFITS ASSOCIATED WITH RECLAMATION PROJECTS, UNTIL RECENTLY, CONSISTED ONLY OF ESTIMATES OF COSTS AND ACREAGE TO BE IRRIGATED. THE ESTIMATES OF ACREAGE TO BE IRRIGATED HAVE BEEN ASSUMED TO REPRESENT THE ESTIMATES OF BENEFITS TO BE DERIVED FROM A PROJECT.[1] WHILE SUCH AN ASSUMPTION LIMITS THE CONSIDERATION OF RECLAMATION PROJECT FUNCTIONS TO IRRIGATION, IRRIGATION HAS TRADITIONALLY BEEN THE PRIMARY FUNCTION OF RECLAMATION PROJECTS. TABLE 5, PAGE 75, EMPHASIZES THAT THE IRRIGATION SERVICE PROVIDED BY RECLAMATION PROJECTS HAS ABSORBED THE MAJOR PORTION OF THE GOVERNMENT'S RECLAMATION INVESTMENT. TABLE 5 ALSO SHOWS THAT THE ONLY SERVICE PROVIDED BY RECLAMATION INVESTMENTS WHICH MIGHT AFFECT THIS ANALYSIS WOULD BE THE GENERATION OF COMMERCIAL POWER. HOWEVER, SINCE THE ESTIMATED COST OF POWER GENERATION FACILITIES HAS BEEN INCLUDED IN THE ANALYSIS OF

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[1]A FURTHER DISCUSSION OF THIS ASSUMPTION MAY BE FOUND IN APPENDIX A.

TABLE 5. SUMMARY OF COST ALLOCATION BY THE BUREAU OF RECLAMATION FOR ALL PROJECTS[A]

ALLOCATION	PER CENT OF TOTAL ESTIMATED COST	
	REIMBURSABLE	NONREIMBURSABLE[B]
IRRIGATION	60.38	0.90
COMMERCIAL POWER	28.38	0.07
MUNICIPAL, INDUSTRIAL, AND DOMESTIC WATER	2.14	0.01
FLOOD CONTROL	0.33	4.71
INVESTIGATIONS	0.55	--
RECREATION	0.03	0.11
FISH AND WILDLIFE CONSERVATION	0.04	0.85
MEXICAN TREATY SERVICE	0.13	0.01
NOT ALLOCATED	1.31	--
HIGHWAY CONSTRUCTION	--	0.01
BOULDER CITY	--	0.04
TOTALS	93.29	6.71

[A]SOURCE: U. S. BUREAU OF RECLAMATION (81, PP. XIII-XIV).

[B]THIS CATEGORY NOT RECOGNIZED IN RECLAMATION PROJECTS UNTIL 1939.

COST DEVIATIONS, ONLY THE BENEFITS FROM THIS SERVICE HAVE BEEN IGNORED, DUE TO THE LACK OF MEANINGFUL BENEFIT ESTIMATES IN THE AUTHORIZATION DOCUMENTS. THEREFORE, THE INCREMENT OF INVESTMENT NECESSARY TO PROVIDE ALL OTHER SERVICES, AND THE BENEFITS DERIVED FROM ALL FUNCTIONS OTHER THAN IRRIGATION WILL BE ASSUMED TO BE ESTIMATED ACCURATELY OR TO POSSESS THE SAME DISTRIBUTION AS THE ANALYZED DATA.

SINCE THIS STUDY WAS CONCERNED WITH THE RECOGNITION OF THE DISTRIBUTION OF OUTCOMES ASSOCIATED WITH AN ESTIMATED BENEFIT-COST RATIO, NO ATTEMPT WAS MADE TO ANALYZE DATA FROM A LEVEL OF DETAIL GREATER THAN THAT OF THE TOTAL COST OF AN INVESTMENT OR THE TOTAL BENEFITS WHICH HAD BEEN DERIVED FROM AN INVESTMENT. WHILE THIS LEVEL OF DETAIL WOULD NOT ALLOW A COMPREHENSIVE EXAMINATION OF THE VARIATIONS IN INDIVIDUAL COST AND BENEFIT COMPONENTS, AN ANALYSIS OF MORE DETAILED DATA WOULD BE UNDUELY PENALIZED BY THE MAGNITUDE OF DATA WHICH WOULD HAVE TO BE PROCESSED, TO SAY NOTHING OF THE LACK OF AVAILABILITY OF SUCH INFORMATION. FINALLY, THE USE OF COST AND BENEFIT DATA AT THIS SECOND LEVEL OF DETAIL MIGHT, THROUGH AN AGGREGATION PROCESS, TEND TO SMOOTH VARIATIONS ARISING FROM DIFFERENCES IN INVESTIGATORY TECHNIQUES WITHIN A GIVEN PROJECT.

ONE FINAL LIMITATION SHOULD BE MENTIONED IN CONNECTION WITH THE DATA WHICH WERE USED IN THE ANALYSIS. THE RESULTS PROVIDED BY AN ANALYSIS CAN BE NO BETTER THAN THE DATA UPON WHICH THE ANALYSIS HAS BEEN BASED, AND THE PRECISION,

RELEVANCE AND ACCURACY OF DATA WHICH CAN BE CULLED FROM THE RECORD OF A PUBLIC HEARING OR AN AUTHORIZATION DOCUMENT OFTEN LEAVE SOMETHING TO BE DESIRED. HOWEVER, IN SPITE OF THIS LIMITATION, THE DATA ANALYZED DID PROVIDE AN ILLUSTRATION OF THE USE OF THE CONTINGENCY INDEX IN DETERMINING THE DISTRIBUTION OF OUTCOMES ASSOCIATED WITH AN ESTIMATE OF A BENEFIT-COST RATIO.

THE CONTINGENCY INDEX ANALYSIS WAS BASED UPON THE FOLLOWING LIST OF DATA INPUTS FOR EACH PROJECT INCLUDED IN THE SAMPLE:

A. PROJECT CODE NUMBER,

B. PROJECT NAME,

C. YEAR OF AUTHORIZATION,

D. ESTIMATED CONSTRUCTION COSTS AT AUTHORIZATION,

E. YEAR(S) OF ADDITIONAL AUTHORIZATION(S),

F. ESTIMATED CONSTRUCTION COSTS FOR ADDITIONAL AUTHORIZATIONS,

G. ESTIMATED OPERATION AND MAINTENANCE COST PER ACRE AT AUTHORIZATION,

H. ESTIMATED ACREAGE TO BE IRRIGATED,

I. ANNUAL CUMULATIVE COST OF PLANT, PROPERTY, AND EQUIPMENT, BEGINNING WITH 1920,

J. COST OF OPERATION AND MAINTENANCE PER ACRE FOR 1962,

K. ANNUAL ACREAGE UNDER IRRIGATION,

L. Engineering News-Record Construction Cost Index, 1903-1963.

TABLE 4, PAGE 73, PROVIDES AN INDICATION OF THE RELATIVE MAGNITUDE OF THE VARIOUS PROJECT INVESTMENTS AND IRRIGATED ACREAGE BY SUMMARIZING SOME OF THE ABOVE-MENTIONED DATA. DATA ON THE ESTIMATES OF COSTS AND ACREAGE TO BE IRRIGATED PROVIDED IN CONNECTION WITH ADDITIONAL AUTHORIZATIONS WERE INCLUDED IN THIS LIST OF DATA INPUTS IN ORDER TO ASSURE A FAIR ANALYSIS. IF THE SCOPE OR FUNCTION OF THE PROJECT WERE SUFFICIENTLY ALTERED THAT AN ADDITIONAL AUTHORIZATION WAS REQUIRED, ESTIMATES PERTAINING TO SUCH AN ALTERATION SHOULD BE INCLUDED IN THE ANALYSIS.

QUALIFICATIONS OF THE CALCULATIONS

IN ORDER TO OBTAIN A TRUE COMPARISON OF THE ESTIMATES OF COSTS WITH THE ACTUAL EXPENDITURES, IT WAS NECESSARY TO REDUCE THE ESTIMATED AND ACTUAL VALUES OF COSTS TO A COMMON POINT IN TIME, A PROCEDURE RECOMMENDED IN STEP 4A, TABLE 3, PAGE 69. THIS ADJUSTMENT OF THE DATA WAS NECESSARY TO ASSURE THAT THE COMPARISON WOULD NOT BE A FUNCTION OF SOME TIME SERIES. THE ADJUSTMENT WAS ACCOMPLISHED BY DISCOUNTING ALL VALUES TO THE YEAR OF INITIAL CONSTRUCTION AT THE TWO AND ONE-HALF PER CENT INTEREST RATE USED BY THE BUREAU OF RECLAMATION IN THEIR PROJECT FEASIBILITY STUDIES.[1] THIS RATE OF INTEREST WAS USED TO AVOID THE INTRODUCTION OF ANY EXTRANEOUS FACTOR INTO THE ANALYSIS.

AN ASSUMPTION WAS NECESSARY FOR THE PROJECTS CONSTRUCTED

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[1] WHEN THE VALUES TO BE COMPARED "...INVOLVE DIFFERENT MONEY RECEIPTS AND DISBURSEMENTS AT DIFFERENT TIMES, IT IS... ESSENTIAL TO CONSIDER INTEREST." (22, P. 138)

BEFORE 1920. SINCE ANNUAL CONSTRUCTION COSTS COULD ONLY BE COMPUTED AFTER 1920 BECAUSE OF LIMITATIONS OF THE DATA, THE ENTIRE VALUE OF THE CUMULATIVE CONSTRUCTION COST THROUGH 1920, FOR THE TWENTY-ONE PROJECTS UPON WHICH CONSTRUCTION WAS BEGUN BEFORE 1920, WAS ASSUMED TO HAVE BEEN SPENT DURING THE INITIAL YEAR OF CONSTRUCTION. WHILE THIS ASSUMPTION MIGHT BIAS UPWARDS THE ACTUAL COSTS OF THOSE PROJECTS SPENDING A GREAT DEAL OF TIME IN THE CONSTRUCTION STAGE, THE ASSUMPTION SEEMED LOGICAL UNDER THE CIRCUMSTANCES.

IN ADDITION TO REMOVING TIME FROM THE ANALYSIS, PRICE CHANGES IN CONSTRUCTION COSTS WERE ALSO ELIMINATED. THE BUREAU OF RECLAMATION HAS BASED ALL OF ITS ESTIMATES OF CONSTRUCTION COSTS UPON THE PRICE LEVEL EXISTING AT THE TIME OF ESTIMATION.[1] IN ORDER THAT ANY DEVIATIONS FROM ESTIMATED VALUES WOULD BE MEASURED IN TERMS OF COMPARABLE UNITS, THE EFFECT OF VARIATIONS DURING THE PERIOD OF CONSTRUCTION IN CONSTRUCTION COST AND LEVELS WERE ELIMINATED FROM THE ANALYSIS BY REDUCING ALL ESTIMATES OF CONSTRUCTION COSTS AND ALL ACTUAL EXPENDITURES TO A COMMON PRICE LEVEL, THAT OF 1913, USING THE ENR CONSTRUCTION COST INDEX (9).

A STUDY OF THE COST OF RECLAMATION PROJECTS WOULD SEEM TO IMPLY THAT A CONSTRUCTION COST INDEX FOR RECLAMATION PROJECTS MIGHT NOT HAVE RISEN AS RAPIDLY AS THE ENR CONSTRUCTION COST INDEX. A COMPOSITE BUREAU OF RECLAMATION

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[1] WHILE ONE MIGHT PRESENT A VALID ARGUMENT AGAINST A POLICY OF BASING ALL ESTIMATES ON CURRENT PRICES, THIS POLICY HAS NOT BEEN CONSIDERED IN THIS STUDY.

INDEX ROSE 25.1 PER CENT FROM JANUARY 1950 TO JANUARY 1960, WHILE THE ENR CONSTRUCTION COST INDEX ROSE 67.6 PER CENT (21, P. 468). THUS, THE ADJUSTMENTS FOR PRICE CHANGES IN THE ANALYSIS MIGHT HAVE BEEN CONSERVATIVE AND MIGHT HAVE TENDED TO BIAS THE ACTUAL EXPENDITURES DOWNWARD. THIS DOWNWARD BIAS WOULD REDUCE THE DEVIATION BETWEEN ACTUAL AND ESTIMATED VALUES IF THE EXPENDITURES WERE MADE AT SOME TIME AFTER THE YEAR OF AUTHORIZATION. HOWEVER, SINCE MOST PROJECTS WERE BUILT WITHIN A REASONABLE PERIOD OF TIME AFTER AUTHORIZATION, ANY DOWNWARD BIAS SHOULD NOT BE EXCESSIVE.

THREE CALCULATIONS WERE MADE IN THIS ANALYSIS WHICH WERE NOT MENTIONED IN THE ANALYTICAL PROCEDURES OUTLINED IN TABLE 3, PAGE 69. THE FIRST OF THESE CALCULATIONS, RU_C, WOULD REPRESENT THE VALUE OF THE DEVIATIONS OF ACTUAL COSTS FROM THE ESTIMATED COSTS WITHOUT ANY ADJUSTMENTS FOR TIME OR PRICE DIFFERENTIALS. THIS VALUE WOULD BE FOUND AS FOLLOWS:

$$RU_C = \frac{\left[\begin{array}{l}\text{CUMULATIVE COST OF PLANT,}\\ \text{PROPERTY, AND EQUIPMENT}\\ \text{THROUGH 1963}\end{array}\right] - \sum\left[\begin{array}{l}\text{ESTIMATED}\\ \text{CONSTRUCTION}\\ \text{COSTS}\end{array}\right]}{\Sigma(\text{ESTIMATED CONSTRUCTION COSTS})} \quad (26)$$

THE SECOND COMPUTATION NOT MENTIONED PREVIOUSLY WAS USED TO FIND THE DEVIATION OF THE ACTUAL OPERATION AND MAINTENANCE COSTS FROM THE ESTIMATED OPERATION AND MAINTENANCE COSTS, R_M. WHILE ESTIMATED OPERATION AND MAINTENANCE COSTS WERE NOT AVAILABLE FOR ALL PROJECTS, THIS VALUE OF DEVIATIONS WAS FOUND BY THE EQUATION:

$$R_M = \frac{\left[\begin{array}{l}\text{1962 Operation and}\\ \text{Maintenance Cost/Acre}\end{array}\right] - \left[\begin{array}{l}\text{Estimated Operation}\\ \text{and Maintenance}\\ \text{Cost/Acre}\end{array}\right]}{\text{Estimated Operation and Maintenance Cost/Acre}} \quad (27)$$

Finally, an average of the values of the benefit contingency index, ρ_B, the cost contingency index, ρ_C, and the contingency index, ρ_{BC}, by the year of authorization was found in order to determine if any time-related trends in the deviations were evident. For any year of authorization, T, the expected value of ρ_B, ρ_C, and ρ_{BC} for projects authorized in year T would be shown by the values of π_{B_T}, π_{C_T}, and π_{BC_T} respectively. These latter values would be expressed as:

$$\pi_{B_T} = E\left[\rho_{B_T}\right], \quad (28)$$

$$\pi_{C_T} = E\left[\rho_{C_T}\right], \quad (29)$$

$$\pi_{BC_T} = E\left[\rho_{BC_T}\right]. \quad (30)$$

Presentation of Results

The results of the computations performed in accordance with the analytical procedure, outlined in table 3, page 69, and designed to provide information on the characteristics of the distribution of possible outcomes of an estimated benefit-cost ratio, as determined from an analysis of historical data using the contingency index, have been tabulated on the pages which follow. In addition to the calculations necessary for a contingency index analysis, the supplementary calculations mentioned in the previous section of this study have also been included in these tabulations. While the tabulated results

WERE OBTAINED BY COMPUTATIONS PERFORMED ON AN IBM 7074 COMPUTER, A SET OF SAMPLE CALCULATIONS MAY BE FOUND IN APPENDIX B. THE SAMPLE CALCULATIONS HAVE BEEN INCLUDED TO PROVIDE AN ADDITIONAL ILLUSTRATION OF HOW THE CONTINGENCY INDEX, ρ_{BC}, WOULD BE DETERMINED FOR ANY PARTICULAR CAPITAL EXPENDITURE.

THE RESULTS OF THE COMPUTATIONS OF THE UNADJUSTED DEVIATION OF THE ACTUAL COST FROM THE ESTIMATED COSTS, RU_C, EXPRESSED AS A PERCENTAGE DEVIATION FROM EQUATION 26, PAGE 80; THE ADJUSTED DEVIATION OF THE ACTUAL COST FROM THE ESTIMATED COST, R_C', EXPRESSED AS A PERCENTAGE DEVIATION FROM EQUATION 7, PAGE 56; THE DEVIATION OF ACTUAL BENEFITS FROM ESTIMATED BENEFITS, REPRESENTED BY ACREAGE UNDER IRRIGATION, R_B', EXPRESSED AS A PERCENTAGE DEVIATION FROM EQUATION 6, PAGE 56; THE COST CONTINGENCY INDEX, ρ_C, FROM EQUATION 17, PAGE 62; THE BENEFIT CONTINGENCY INDEX, ρ_B, FROM EQUATION 16, PAGE 62; THE CONTINGENCY INDEX, ρ_{BC}, FROM EQUATION 15, PAGE 62; AND THE DEVIATION OF ACTUAL OPERATION AND MAINTENANCE COSTS FROM ESTIMATED OPERATION AND MAINTENANCE COSTS, R_M, EXPRESSED AS A PERCENTAGE DEVIATION FROM EQUATION 27, PAGE 81, HAVE BEEN SHOWN IN TABLE 6, PAGE 83. THE VARIOUS CONTINGENCY INDICES FOR THE INDIVIDUAL PROJECTS WERE AVERAGED AND THE EXPECTED VALUES OF THE OBSERVED BENEFIT CONTINGENCY INDEX, I_B, FROM EQUATION 18, PAGE 65; THE OBSERVED COST CONTINGENCY INDEX, I_C, FROM EQUATION 19, PAGE 65; AND THE OBSERVED CONTINGENCY INDEX, I_{BC}, FROM EQUATION 20, PAGE 65, HAVE BEEN SHOWN IN

TABLE 6. ANALYSIS OF ESTIMATES OF COSTS AND IRRIGATED ACREAGE MADE FOR RECLAMATION PROJECTS AUTHORIZED PRIOR TO 1939

PROJECT	RU_C %	R'_C %	R'_B %	ρ_C	ρ_B	ρ_{BC}	R_M %
ALL-AMERICAN CANAL	7.19	-24.77	-49.09	0.2846	-0.6752	-0.3906	(A)[A]
BAKER	12.51	50.71	- 1.63	-0.4102	-0.0164	-0.4266	(A)
BELLE FOURCHE	139.42	70.47	-10.22	-0.5848	-0.1078	-0.6926	465.00
BITTER ROOT	78.60	42.88	-12.73	-0.3569	-0.1361	-0.4930	312.96
BOISE	68.33	-13.96	-12.64	0.1504	-0.1351	0.0153	(A)
BUFFALO RAPIDS	36.50	- 6.43	-30.76	0.0665	-0.3676	-0.3011	44.33
BURNT RIVER	9.28	- 7.41	- 2.34	0.0770	0.0232	0.1002	(A)
CARLSBAD	41.40	47.41	-21.26	-0.3881	-0.2391	-0.6271	597.78
CENTRAL VALLEY	- 0.88	-19.08	-49.86	0.2118	-0.6904	-0.4786	597.78
COLORADO-BIG THOMPSON	259.50	44.14	10.24	-0.3656	0.0975	-0.2681	- 8.16
COLUMBIA BASIN	9.85	-19.43	-82.05	0.2161	-1.7174	-1.5013	188.00
DESCHUTES	48.29	-19.82	84.36	0.2209	0.6117	0.8326	421.00
FRENCHTOWN	26.96	5.14	-46.08	-0.0501	-0.6176	-0.6677	(A)
FRUITGROWERS DAM	0.16	- 3.08	- 6.83	0.0313	-0.0708	-0.0395	-59.00
GILA	5.99	-16.79	-43.99	0.1838	-0.5796	-0.3958	(A)
GRAND VALLEY	81.50	16.19	-40.27	-0.1501	-0.5153	-0.6654	180.80
HUMBOLDT	-33.13	-40.50	-34.40	0.5192	-0.4217	0.0975	(A)
HUNTLEY	107.50	63.10	-30.86	-0.4892	-0.3690	-0.8582	455.00
HYRUM	2.34	- 2.27	-51.07	0.0230	-0.7148	-0.6918	(A)
KENDRICK	2.01	-33.94	-74.93	0.4146	-1.3834	-0.9689	170.00
KLAMATH	61.68	- 7.97	-17.33	0.0830	-0.1903	-0.1073	542.67
LOWER YELLOWSTONE	198.83	161.42	19.52	-0.9609	0.1783	-0.7827	193.64
MILK RIVER	193.73	293.70	-35.92	-1.3704	-0.4451	-1.8155	(A)
MINIDOKA	-64.21	10.60	275.65	-0.1008	1.2744	1.1736	1058.33
MOON LAKE	19.99	-11.09	-16.00	0.1176	-0.1743	-0.0568	(A)
NEWLANDS	526.80	441.97	-60.71	-1.6900	-0.9342	-2.6243	715.00
NORTH PLATTE	169.43	102.46	-29.34	-0.7054	-0.3473	-1.0527	47.00
OGDEN RIVER	54.14	12.86	-22.74	-0.1210	-0.2580	-0.3790	(A)
OKANOGAN	236.86	171.12	-53.25	-0.9974	-0.7603	-1.7577	18.60
ORLAND	387.64	119.17	23.36	-0.7847	0.2099	-0.5747	(A)
OWYHEE	- 8.60	-14.32	-13.10	0.1546	-0.1404	0.0141	(A)
PINE RIVER	7.09	- 3.50	-36.06	0.0356	-0.4472	-0.4115	1040.91
PROVO RIVER	131.17	38.32	-54.17	-0.3244	-0.7802	-1.1046	(A)
RIO GRANDE	138.74	214.25	- 2.35	-1.1450	-0.0238	-1.1688	172.80
RIVERTON	264.38	41.84	-47.33	-0.3495	-0.6411	-0.9906	(A)
SALT RIVER	619.43	342.63	22.73	-1.4876	0.2048	-1.2828	4636.59
SANPETE	15.72	-16.39	- 6.74	0.1790	-0.0698	0.1092	(A)
SHOSHONE	141.18	14.16	-15.12	-0.1324	-0.1639	-0.2964	233.00
STRAWBERRY VALLEY	178.34	179.01	-19.35	-1.0261	-0.2150	-1.2411	(A)
SUN RIVER	7.11	-45.80	-75.17	0.6126	-1.3930	-0.7804	456.00
TRUCKEE STORAGE	9.24	5.89	-27.61	-0.0573	-0.3231	-0.3803	(A)
TUCUMCARI	94.01	21.17	-26.32	-0.1920	-0.3054	-0.4974	362.40
UMATILLA	415.22	221.29	20.75	-1.1672	0.1885	-0.9786	315.38
UNCOMPAHGRE	287.79	176.65	-33.03	-1.0176	-0.4009	-1.4185	(A)
VALE	114.66	33.24	- 3.27	-0.2870	-0.0332	-0.3202	(A)
W. C. AUSTIN	118.17	44.53	-40.97	-0.3683	-0.5272	-0.8955	307.00
WEBER RIVER	- 9.22	- 9.85	13.60	0.1037	0.1275	0.2312	(A)
YAKIMA	76.18	24.53	-10.11	-0.2194	-0.1065	-0.3259	13.17
AVERAGE	110.35[B]	32.42	-26.15	-0.2808	-0.3025	-0.5834	498.52

[A]ESTIMATE NOT AVAILABLE.

[B]WEIGHTED AVERAGE = 260.57%.

TABLE 7. VALUES OF THE CONTINGENCY INDEX AND THE ACCURACY INDEX FOR RECLAMATION PROJECTS AUTHORIZED PRIOR TO 1939

CONTINGENCY INDEX	
I_B	-0.30254
I_C	-0.28082
I_{BC}	-0.58336
ACCURACY INDEX	
J_B	0.23842
J_C	0.28824
J_{BC}	0.42646
COEFFICIENT OF CORRELATION OF ρ_B WITH ρ_C	-0.19110

TABLE 7, PAGE 84. TABLE 7 ALSO HAS LISTED THE VALUES OF THE VARIANCES ASSOCIATED WITH THE PREVIOUSLY MENTIONED EXPECTED VALUES, THAT IS, THE VALUES OF THE BENEFIT ACCURACY INDEX, d_B, FROM EQUATION 22, PAGE 66; THE COST ACCURACY INDEX, d_C, FROM EQUATION 23, PAGE 66; AND THE ACCURACY INDEX, d_{BC}, FROM EQUATION 24, PAGE 67. FINALLY, THE VALUE OF THE CORRELATION COEFFICIENT OF ρ_B WITH ρ_C HAS BEEN SHOWN IN TABLE 7 ALSO. WHILE THE CORRELATION COEFFICIENT WOULD BE SMALL ENOUGH THAT ONE MIGHT BE WILLING TO ASSUME THAT NO CORRELATION EXISTS BETWEEN ρ_B AND ρ_C, SUCH AN ASSUMPTION WAS NOT MADE IN DETERMINING THE VALUE OF THE ACCURACY INDEX, d_{BC}. THE LAST SET OF CALCULATIONS HAS BEEN SHOWN IN TABLE 8, PAGE 86. THE VALUES SHOWN IN TABLE 8 REPRESENT THE EXPECTED VALUES OF THE CONTINGENCY INDICES GROUPED ACCORDING TO THE YEAR OF INITIAL PROJECT AUTHORIZATION, THAT IS, VALUES OF π_{B_T} FROM EQUATION 28, PAGE 81; π_{C_T} FROM EQUATION 29, PAGE 81; AND π_{BC_T} FROM EQUATION 30, PAGE 81.

THE VALUES OF THE PERCENTAGE DEVIATIONS OF BENEFITS AND COSTS, R'_B, RU_C, AND R'_C, RESPECTIVELY WERE INCLUDED AS SUPPLEMENTARY CALCULATIONS IN THIS ANALYSIS BECAUSE OF THE GENERAL PUBLIC ACCEPTANCE AND UNDERSTANDING OF SUCH VALUES. WHILE THESE VALUES DO NOT PROVIDE THE MEASURE OF THE EFFECT OF COMPONENT DEVIATIONS UPON THE BENEFIT-COST RATIO PROVIDED BY THE CONTINGENCY INDICES, THE VALUES OF PERCENTAGE DEVIATIONS DO PROVIDE INFORMATION PERTINENT TO THE DEVIATIONS FROM THE ESTIMATED VALUES WHICH HAVE OCCURRED IN THE INDIVIDUAL COST

TABLE 8. VALUES OF THE CONTINGENCY INDEX GROUPED AND AVERAGED ACCORDING TO THE YEAR OF AUTHORIZATION

YEAR t	NUMBER OF PROJECTS	π_{B_T}	π_{C_T}	π_{BC_T}
1903	2	-0.3647	-1.5888	-1.9535
1904	3	0.2365	-0.4169	-0.1804
1905	4	-0.1615	-0.6851	-0.8466
1906	10	-0.3320	-0.5468	-0.8787
1908	1	0.2099	-0.7847	-0.5747
1913	1	-0.5153	-0.1501	-0.6654
1920	1	-0.6411	-0.3495	-0.9906
1927	2	0.0471	-0.0915	-0.0444
1928	1	-0.1404	0.1546	0.0142
1930	1	-0.1361	-0.2318	-0.3680
1931	1	-0.0164	-0.4066	-0.4231
1934	5	-0.6411	0.1427	-0.4984
1935	3	-0.3697	0.2160	-0.1537
1936	1	0.0232	0.0770	0.1002
1937	2	-0.3453	0.0072	-0.3381
1938	5	-0.1178	-0.0802	-0.1980
1940	1	-0.3054	-0.1915	-0.4969
1941	1	-0.5272	-0.3675	-0.8947
1943	1	-1.7174	0.2178	-1.4996
1946	1	-0.6904	0.2124	-0.4780
1947	1	-0.5796	0.1847	-0.3949

AND BENEFIT COMPONENTS.

UPON EXAMINATION OF TABLE 6, PAGE 83, THE LARGE DIFFERENCE EXISTING BETWEEN ADJUSTED AND UNADJUSTED VALUES OF COST DEVIATIONS WERE IMMEDIATELY EVIDENT. FOR THE PROJECTS ANALYZED IN THIS SAMPLE, THE AVERAGE ADJUSTED DEVIATION OF COSTS, $\overline{R_c}$, INDICATED THAT THE ACTUAL COSTS HAD EXCEEDED THE ESTIMATED COSTS BY 32.42 PER CENT. HOWEVER, WHEN THE COSTS WERE NOT REDUCED TO AN EQUIVALENT POINT IN TIME AND TO DOLLAR UNITS OF THE SAME VALUE, THE AVERAGE UNADJUSTED COST DEVIATION, $\overline{RU_c}$, INDICATED THAT THE ACTUAL COSTS EXCEEDED THE ESTIMATED COSTS BY 110.35 PER CENT. SUCH A PRONOUNCED DIFFERENCE BETWEEN $\overline{R_c}$ AND $\overline{RU_c}$ WOULD SEEM TO IMPLY THAT VARIATIONS IN CONSTRUCTION COST LEVELS AND TIME OF DISBURSEMENT WOULD ACCOUNT FOR A LARGE PORTION OF THE APPARENT VARIATION FROM THE ESTIMATED COSTS EXHIBITED BY THE PROJECTS IN THIS SAMPLE. THIS CONCLUDED POINT, THAT IS, THAT PRICE VARIATIONS WERE QUITE IMPORTANT IN ACCOUNTING FOR DEVIATIONS FROM THE ESTIMATED PROJECT COSTS, HAS BEEN SUPPORTED BY INFORMATION PRESENTED IN HEARINGS BEFORE THE HOUSE COMMITTEE ON PUBLIC WORKS OF THE 82D CONGRESS (110). TABLE 9, PAGE 88, SUMMARIZES SOME OF THE INFORMATION PRESENTED AT THESE HEARINGS AND SHOWS THE BUREAU OF RECLAMATION ATTRIBUTED 30.2 PER CENT OF THE UNADJUSTED COST INCREASE ON RECLAMATION PROJECTS TO CHANGES IN THE PRICE LEVEL. IN CONNECTION WITH TABLE 9, THE PERCENTAGE OF THE COST INCREASES ACCOUNTED FOR BY CHANGES AUTHORIZED BY LAW, 43.3 PER CENT, WERE NOT THE RESULT OF REAUTHORIZATIONS; RATHER,

TABLE 9. ANALYSIS OF COMPONENTS OF COST INCREASES[A]

SOURCE	PERCENTAGE OF INCREASES BY CATEGORIES OF CAUSE	
	BUREAU OF RECLAMATION	CORPS OF ENGINEERS
PRICE CHANGES	30.2	57.8[B]
CHANGES AUTHORIZED BY LAW	43.3[C]	17.6
STRUCTURAL AND ENGINEERING MODIFICATIONS	2.8	6.3
CHANGES TO SUIT LOCAL NEEDS	2.8	4.1
UNFORESEEN CONDITIONS	3.8	8.5
NATIONAL EMERGENCY	1.0	--
INADEQUACY IN PLANNING	5.7	5.7
ADMINISTRATIVE DECISIONS	8.0	--
OTHER	2.9	--
TOTAL	100.0[D]	100.0[D]

[A]SOURCE: U. S. CONGRESS (110, P. 17).

[B]MANY PROJECTS ARE AUTHORIZED ON THE BASIS OF PRELIMINARY ESTIMATES, REMAINDER 1936 FLOOD CONTROL AUTHORIZATIONS BASED ON "308" SURVEYS.

[C]ITEMS NOT INCLUDED IN THE ORIGINAL ESTIMATE PLUS THE COST OF THE FEASIBILITY STUDY FOR THESE ITEMS.

[D]TOTAL AS SHOWN IN HOUSE COMMITTEE PRINT. ERROR ASSUMED TO BE DUE TO ROUNDING OF ESTIMATES.

THESE CHANGES WERE THE RESULT OF DEVIATIONS FROM THE AUTHORIZED PLAN. THESE DEVIATIONS WERE ALLOWED BECAUSE THE DEVELOPMENT PLANS HAD BEEN DRAWN UP LOOSELY ENOUGH THAT A GREAT VARIETY OF CHANGES WERE POSSIBLE WITHOUT SEEKING OFFICIAL APPROVAL. THE DIFFERENCE IN THE DEVIATIONS OF THE UNADJUSTED COSTS AND THE ADJUSTED COSTS WERE EVEN MORE PRONOUNCED WHEN AN AVERAGE DEVIATION WAS CALCULATED USING THE ACTUAL COSTS FOR EACH PROJECT AS A WEIGHTING FACTOR. THIS WEIGHTED AVERAGE DEVIATION WAS 260.57 PER CENT. THE DIFFERENCE BETWEEN THE WEIGHTED, UNADJUSTED VALUE OF 260.57 PER CENT AND THE UNWEIGHTED, UNADJUSTED VALUE OF 110.35 PER CENT WOULD SEEM TO IMPLY THAT THE LARGER THE INVESTMENT, THE GREATER THE DEVIATION FROM THE COST ESTIMATE. A POSSIBLE REASON FOR THIS TREND, A TREND NOT EXHIBITED IN THE ADJUSTED VALUES, COULD BE THAT THE LARGER INVESTMENTS REQUIRED A LONGER PERIOD OF TIME TO COMPLETE THEIR CONSTRUCTION; THUS, THESE PROJECTS WOULD BE MORE VULNERABLE TO TIME RELATED, EXTERNAL VARIATIONS, SUCH AS CHANGES IN THE PRICE LEVEL. THEREFORE, THE PRINCIPAL REASON FOR INCLUDING THE CALCULATION OF UNADJUSTED PRICE DEVIATIONS, RU_C, IN THIS ANALYSIS WAS TO EMPHASIZE THE IMPORTANCE OF ADJUSTING FOR PRICE AND TIME TRENDS IN ANY ANALYSIS OF HISTORICAL DATA WHICH HAS BEEN USED TO MAKE INFERENCES UPON THE DISTRIBUTION OF POSSIBLE OUTCOMES OF PROPOSED EXPENDITURES. A PLOT OF THE DENSITY FUNCTION OF RU_C, TAKEN FROM A PLOT OF A HISTOGRAM, HAS BEEN SHOWN IN ILLUSTRATION 4, PAGE 90. THIS ILLUSTRATION DEMONSTRATES

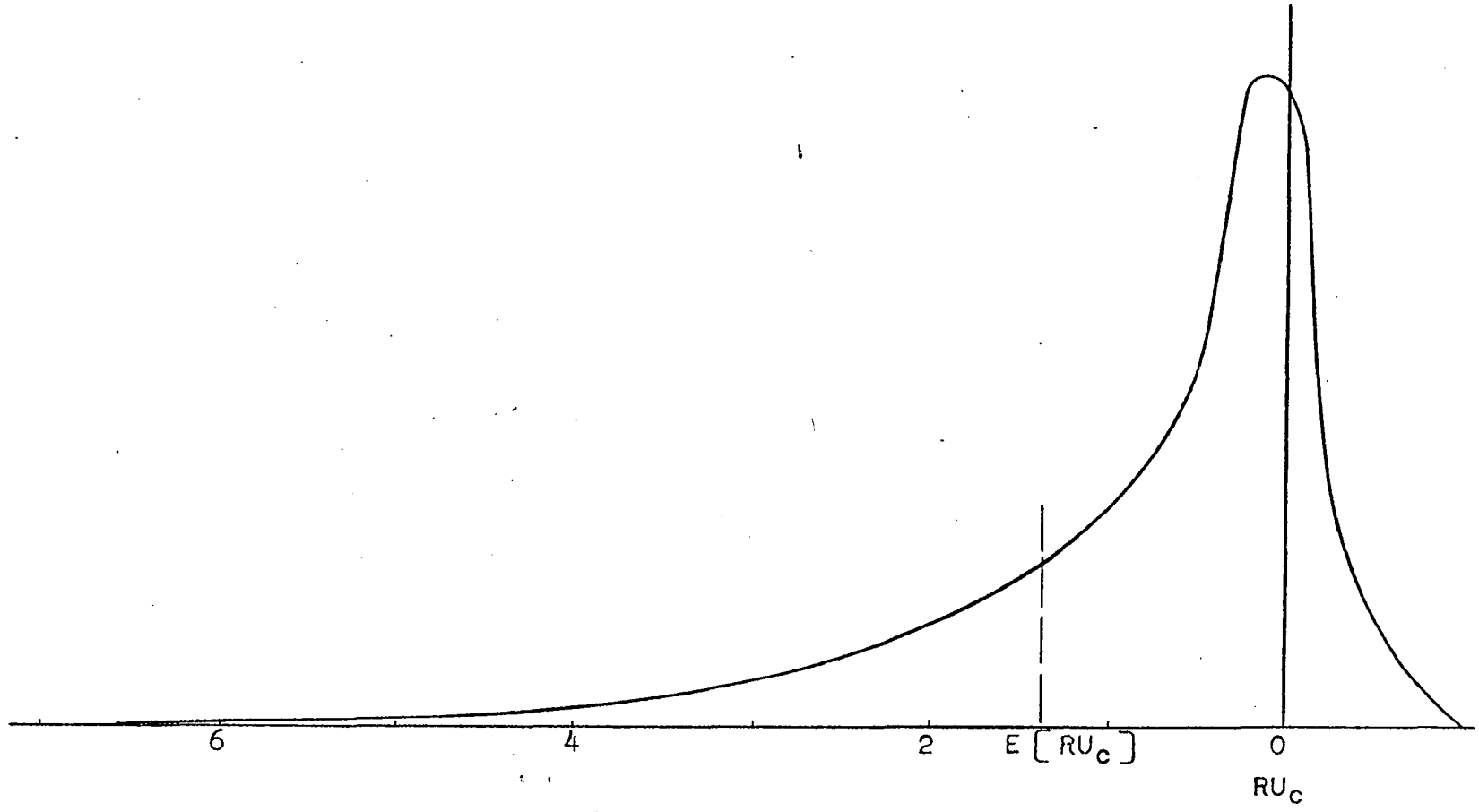

ILLUSTRATION 4. DISTRIBUTION OF UNADJUSTED DEVIATIONS FROM ESTIMATED COSTS, RU_c

THE PRONOUNCED SKEWNESS OF THE UNADJUSTED DISTRIBUTION COMPARED TO THE DISTRIBUTION OF THE COST CONTINGENCY INDEX, ρ_C, PLOTTED IN ILLUSTRATION 6, PAGE 96.

DISTRIBUTION RECOGNITION

> GOVERNMENT, UNDER WHATEVER POINT OF VIEW WE EXAMINE THIS TOPIC, IS UNFORTUNATELY PREGNANT WITH MOTIVES TO CENSURE AND COMPLAINT. INCESSANT CHANGE, EVERLASTING INNOVATION, SEEM TO BE DICTATED BY THE TRUE INTEREST OF MANKIND. BUT THE GOVERNMENT IS THE PERPETUAL ENEMY OF CHANGE. WHAT WAS ADMIRABLY OBSERVED OF A PARTICULAR SYSTEM OF GOVERNMENT, IS IN A GREAT DEGREE TRUE OF ALL: THEY "LAY THEIR HAND ON THE SPRING THERE IS IN SOCIETY, AND PUT A STOP TO ITS MOTION." THEIR TENDENCY IS TO PERPETUATE ABUSE. WHATEVER WAS ONCE THOUGHT RIGHT AND USEFUL, THEY UNDERTAKE TO ENTAIL TO THE LATEST POSTERITY. THEY REVERSE THE GENUINE PROPENSITIES OF MAN, AND, INSTEAD OF SUFFERING US TO PROCEED, TEACH US TO LOOK BACKWARDS FOR PERFECTION. ... [I]N A TIMID REVERENCE FOR THE DECISIONS OF OUR ANCESTORS, AS IF IT WERE THE NATURE OF THE HUMAN MIND, ALWAYS TO DEGENERATE, AND NEVER TO ADVANCE. (20, P. 178)

THE ROLE PLAYED BY THE UNCERTAINTY INHERENT TO ESTIMATES OF BENEFITS, COSTS, AND THE BENEFIT-COST RATIO IN PRODUCING DEVIATIONS FROM THE ESTIMATED OUTCOMES SEEMS TO HAVE BEEN EITHER IGNORED OR OVERLOOKED IN THE EXISTING METHODS OF ANALYZING THE FEASIBILITY OF GOVERNMENTAL CAPITAL EXPENDITURES. THIS INQUIRY HAS STRESSED THE CONTENTION THAT KNOWLEDGE OF THE CHARACTERISTICS OF THE DISTRIBUTION OF POSSIBLE OUTCOMES ASSOCIATED WITH ANY ESTIMATED OUTCOME WOULD PROVIDE NOT ONLY AN INDICATION OF THE TRUE EXPECTED VALUE OF THE OUTCOME, BUT ALSO AN INDICATION OF WHAT THE VARIANCE OF THE DISTRIBUTION MIGHT BE. THE VARIANCE COULD BE USED TO ESTABLISH A CONFIDENCE INTERVAL WHICH WOULD PROVIDE THE DECISION-MAKER WITH A RANGE OF POSSIBLE OUTCOMES WITHIN WHICH THE ACTUAL OUTCOME SHOULD FALL.

SINCE THE DEVIATIONS OF ACTUAL COSTS AND BENEFITS FROM THEIR ESTIMATED VALUES IN THE EXAMPLE IN THE PREVIOUS CHAPTER WERE PROVEN TO BE OF SIGNIFICANT MAGNITUDE TO WARRANT FURTHER ATTENTION, THE PROBLEM THEN ARISES AS TO HOW A DISTRIBUTION OF POSSIBLE OUTCOMES MIGHT BE FOUND IN ACTUAL PRACTICE. TWO METHODS OF DETERMINING THE CHARACTERISTICS OF SUCH A DISTRIBUTION WOULD BE AVAILABLE TO THE ANALYST. THE FIRST OF THESE METHODS WOULD BE THE USE OF THE CONTINGENCY INDEX AS OUTLINED IN TABLE 3, PAGE 69. RECOGNITION OF THE DISTRIBUTION ASSOCIATED WITH PAST BENEFIT-COST ESTIMATES AND THE APPLICATION OF THE CHARACTERISTICS OF THIS DISTRIBUTION TO THE REFINEMENT OF FUTURE ESTIMATES HAVE BEEN ILLUSTRATED IN THE FIRST SECTION OF THIS CHAPTER. IF, HOWEVER, HISTORICAL DATA WERE NOT AVAILABLE, OR THE USE OF SUCH DATA WERE NOT DEEMED TO BE ACCEPTABLE FOR THE PURPOSES OF DRAWING INFERENCES FOR USE ON FUTURE ESTIMATES, THE USE OF THE CONTINGENCY INDEX AS A METHOD OF RECOGNIZING THE DISTRIBUTION ASSOCIATED WITH ESTIMATES OF THE BENEFIT-COST RATIO FOR PROPOSED CAPITAL EXPENDITURES WOULD NOT BE PRACTICAL. ESTIMATED BENEFIT-COST RATIO DISTRIBUTIONS MAY STILL BE RECOGNIZED WITHOUT THE USE OF HISTORICAL DATA BY THE SECOND METHOD PROPOSED IN THE LATTER PART OF THIS CHAPTER. THIS METHOD WOULD UTILIZE MULTIVALUED ESTIMATES TO DETERMINE THE CHARACTERISTICS OF AN APPROXIMATE DISTRIBUTION ASSOCIATED WITH A BENEFIT-COST ESTIMATE.

Determination of Distribution Characteristics with the Contingency Index

The procedure to be used in applying the contingency index to the determination of the characteristics of a distribution of outcomes of past benefit and cost estimates, a procedure outlined in table 3, page 69, indicates that after the values of the various contingency indices have been found, the frequency distributions of these indices could be plotted in order to discover what the characteristic shape of the frequency distributions might be. The cumulative distribution of the cost contingency index, ρ_c, from which the frequency distribution was derived, has been plotted in illustration 5, page 95.[1] The frequency distribution of ρ_c has been shown in illustration 6, page 96. The slope of the cumulative distribution had sufficient variations that the frequency distribution of ρ_c might have been drawn with several peaks rather than the shape shown in illustration 6. While this distribution has a marked shift to the left of zero, the point of accurate estimation, the distribution does not exhibit marked skewness. Although the logarithmic index would tend to produce a more symmetrical distribution, this lack of definite skewness was surprising.

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[1] By plotting the cumulative distribution and then using the slopes of this curve to determine the frequency distribution, a smoother frequency distribution usually results. In addition, a frequency distribution plotted in this manner does not have the tendency to be affected by the grouping bias often associated with a histogram.

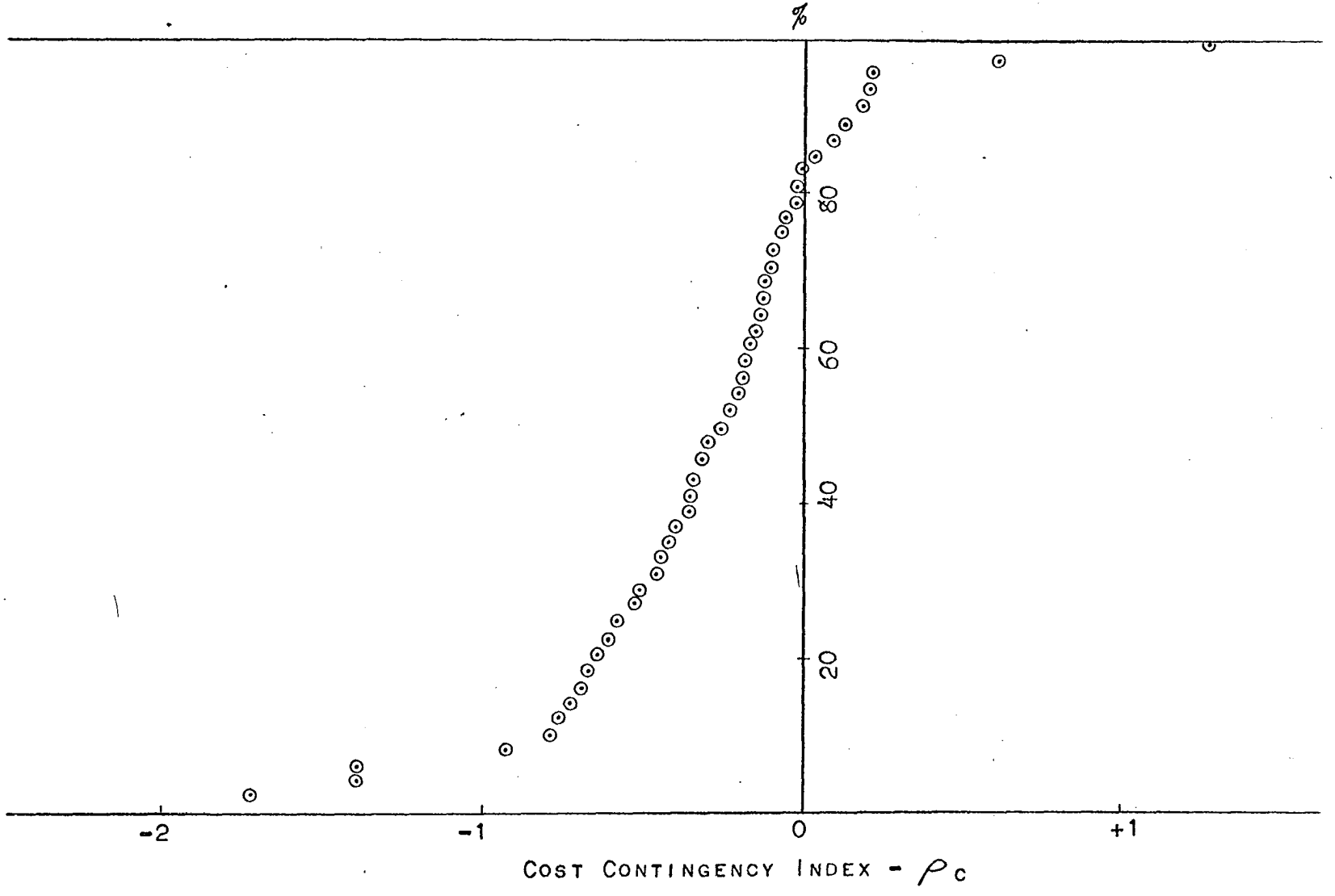

ILLUSTRATION 5. CUMULATIVE DISTRIBUTION OF THE COST CONTINGENCY INDEX

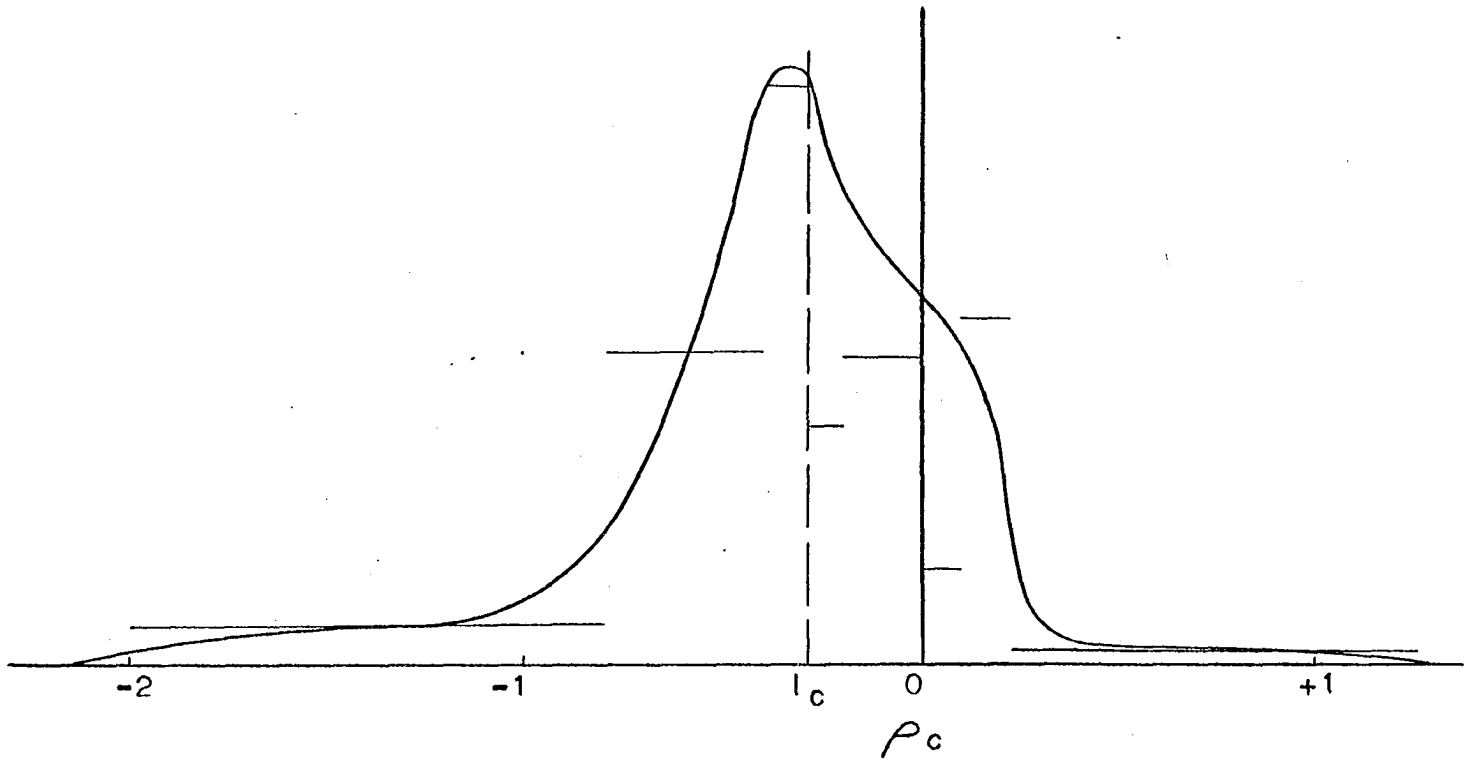

ILLUSTRATION 6. COST CONTINGENCY INDEX, ρ_c, DENSITY FUNCTION

A CUMULATIVE DISTRIBUTION OF THE BENEFIT CONTINGENCY INDEX WAS PLOTTED IN ILLUSTRATION 7, PAGE 98, AND THE FREQUENCY DISTRIBUTION OF THE BENEFIT CONTINGENCY INDEX, ρ_B DERIVED FROM THE SLOPES OF THIS CURVE, WAS SHOWN IN ILLUSTRATION 8, PAGE 99. THE FREQUENCY DISTRIBUTION OF ρ_B WAS MORE REGULAR THAN THE DISTRIBUTION OF ρ_C; HOWEVER, THE MODE OF THE DISTRIBUTION OF ρ_B LAY TO THE RIGHT OF THE EXPECTED VALUE OF THE DISTRIBUTION. THE NEGATIVE EXPECTED VALUE OF ρ_B IMPLIES THAT THE ANALYSTS HAD A PRONOUNCED TENDENCY TO OVERESTIMATE THE ACREAGE WHICH WOULD BE PLACED UNDER IRRIGATION IN RECLAMATION PROJECTS. IN FACT, EXCEPT FOR THE LARGE ACREAGE SUPPLIED WITH SUPPLEMENTAL IRRIGATION WATER IN THE MINIDOKA PROJECT ($\rho_B = 1.1736$), THE ACREAGE TO BE IRRIGATED HAS BEEN CONSISTENTLY OVERESTIMATED.

TABLE 4, PAGE 73, ALSO HAS PROVIDED AN INDICATION OF THE EFFECT OF THE MISESTIMATION OF THE BENEFIT AND COST COMPONENTS UPON THE BENEFIT-COST RATIO FOR BOTH THE INDIVIDUAL PROJECTS AND THE ENTIRE GROUP OF PROJECTS. UNFORTUNATELY, THE COSTS WERE GENERALLY UNDERESTIMATED WHILE THE BENEFITS WERE OVER-ESTIMATED, WITH A NET RESULT THAT THE COMPONENT DEVIATIONS COMBINED TO AMPLIFY THE DEVIATION FROM THE EXPECTED BENEFIT-COST RATIO.[1] THE PERCENTAGE DEVIATION OF THE BENEFIT-COST

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[1] NO BENEFIT-COST RATIO WAS ACTUALLY CALCULATED AT THE TIME OF AUTHORIZATION FOR THE PROJECTS IN THIS ANALYSIS; HOWEVER, THIS DOES NOT DIMINISH THE AFFECTS THAT THESE COMPONENT DEVIATIONS WOULD HAVE UPON THE ECONOMIC FEASIBILITY OF A PROJECT.

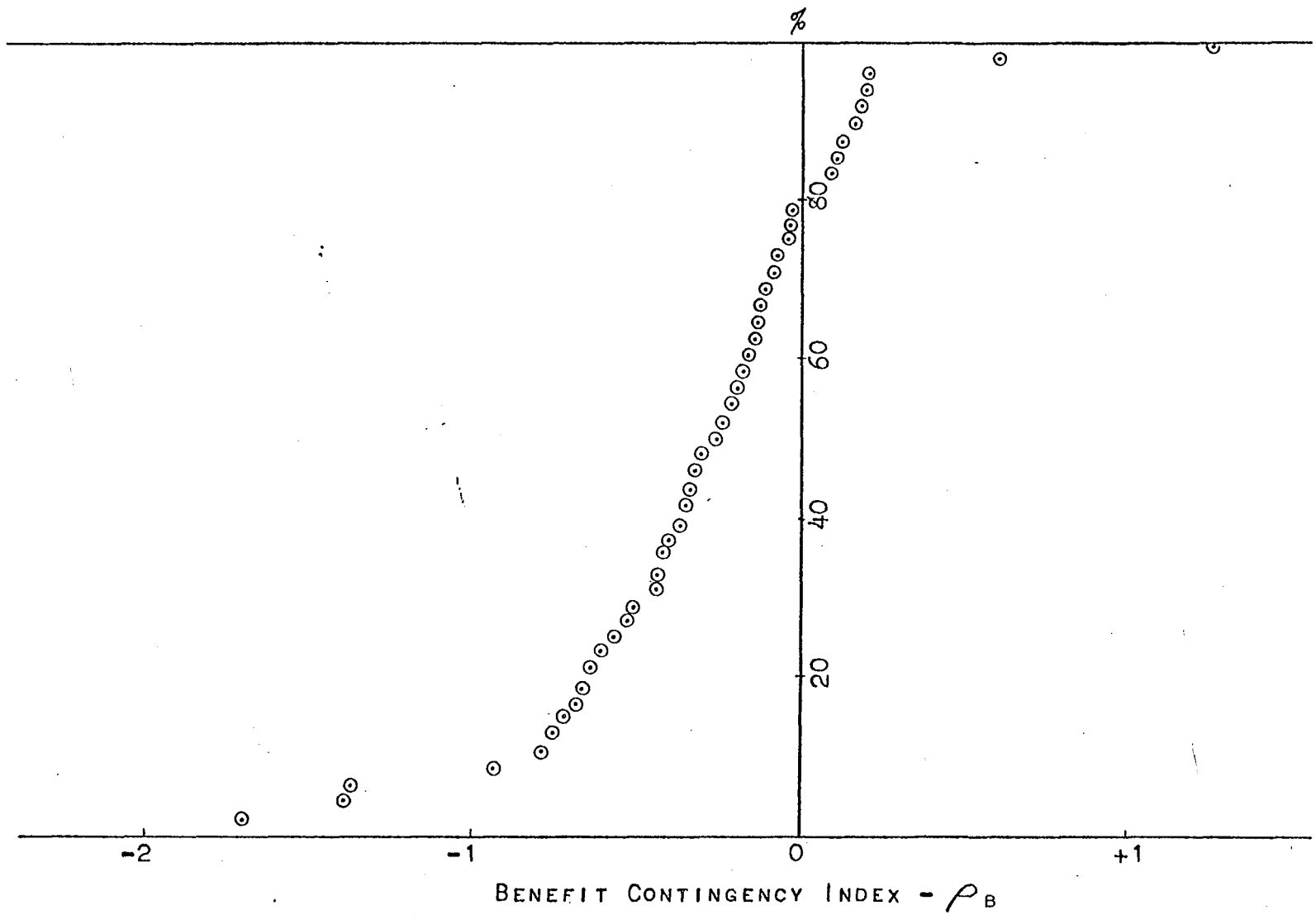

ILLUSTRATION 7. CUMULATIVE DISTRIBUTION OF BENEFIT CONTINGENCY INDEX

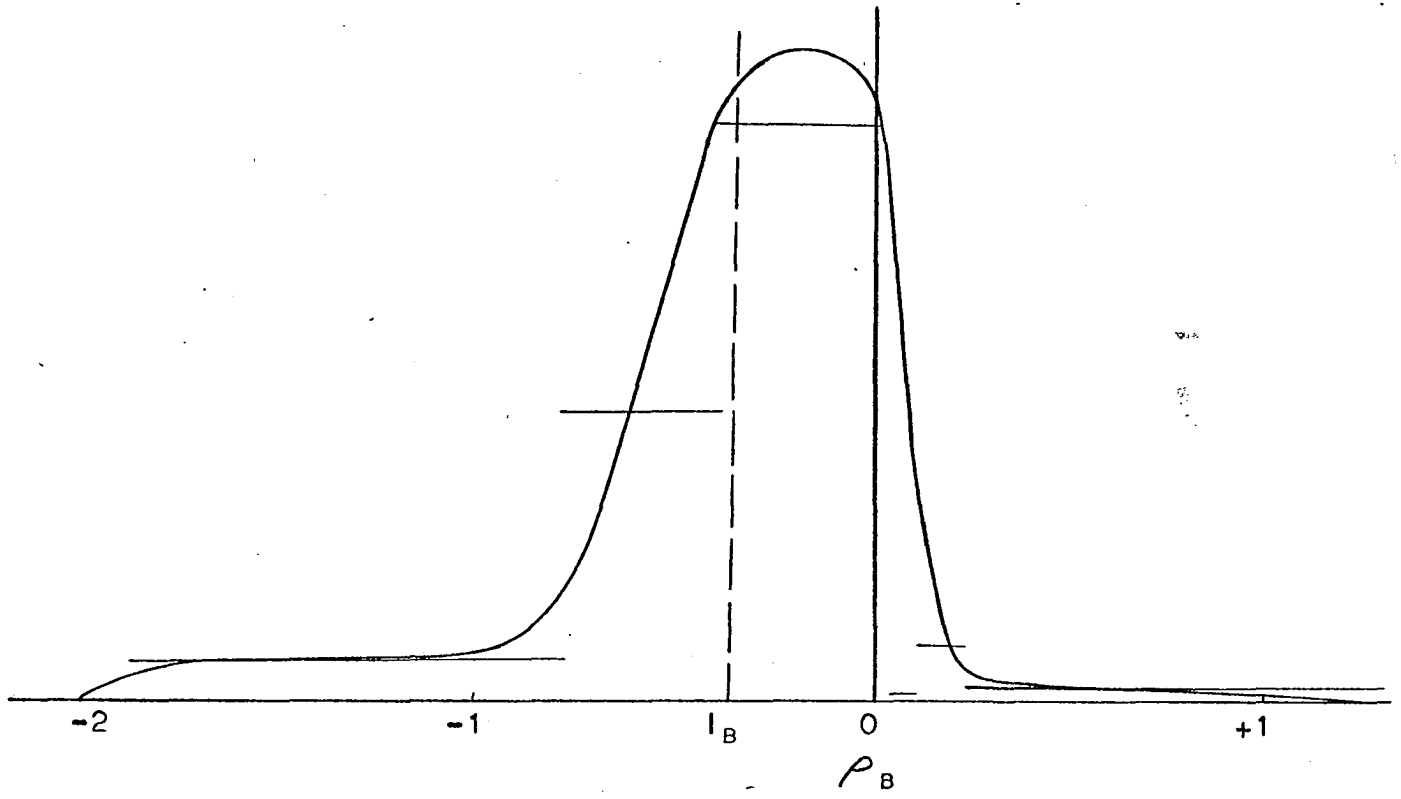

ILLUSTRATION 8. BENEFIT CONTINGENCY INDEX, ρ_B, DENSITY FUNCTION

RATIO WOULD BE 44.2 PER CENT FOR AN AVERAGE OF ALL PROJECTS.[1] THIS AMPLIFICATION OF THE DEVIATIONS IN BENEFIT-COST RATIOS UNDER THE CONDITIONS OF COST UNDERESTIMATION AND BENEFIT OVERESTIMATION IS GRAPHICALLY ILLUSTRATED BY THE ADDITIVE NATURE OF THE CONTINGENCY INDICES. THE CHARACTERISTIC OF THE CONTINGENCY INDEX OF INDICATING IN A SIMPLE MANNER WHETHER OR NOT POSSIBLE DEVIATIONS FROM EXPECTED OUTCOMES OF BENEFITS AND COSTS WOULD CANCEL TO LEAVE THE BENEFIT-COST RATIO UNCHANGED OR WOULD ADD TO CAUSE GREATER DEVIATIONS IN THE BENEFIT-COST RATIO THAN WERE PRESENT IN EITHER OF THE COMPONENTS WOULD BE ONE OF THE ADVANTAGES OF THE LOGARITHMIC NATURE OF THE INDEX.

AN ILLUSTRATION OF THE PATTERN OF COMPONENT DEVIATIONS IN THE SAMPLE CHOSEN FOR ANALYSIS IS SHOWN BY THE SCATTER DIAGRAM OF THE VALUES OF THE INDIVIDUAL CONTINGENCY INDICES, ρ_{BC}, IN ILLUSTRATION 9, PAGE 101. AS ONE WOULD SUSPECT FROM THE VALUES OF THE COST AND BENEFIT CONTINGENCY INDICES, THIS SCATTER DIAGRAM HAS SHOWN THAT THE MAJORITY OF PROJECTS HAVE FALLEN WITHIN THE AREA WHICH REPRESENTS AN INFLATED ORIGINAL BENEFIT-COST RATIO. PROJECTS WHOSE COMPONENT CONTINGENCY INDICES PLACE THEM IN THE REGION REPRESENTING A NEGATIVE ρ_{BC}

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[1] TO FIND THE PERCENTAGE DEVIATION OF BENEFITS, R_B, FROM THE BENEFIT CONTINGENCY INDEX, TAKE THE ANTILOG OF ρ_B; SUBTRACT THIS VALUE FROM 1.0 AND MULTIPLY BY 100. TO FIND THE PERCENTAGE DEVIATION FROM THE COST CONTINGENCY INDEX, TAKE THE RECIPROCAL OF THE ANTILOG OF ρ_C; SUBTRACT 1.0 FROM THIS VALUE AND MULTIPLY BY 100. FINALLY, TO FIND THE PERCENTAGE DEVIATION FOR THE BENEFIT-COST RATIO, TAKE THE ANTILOG OF ρ_{BC}; SUBTRACT THIS FROM 1.0 AND MULTIPLY BY 100.

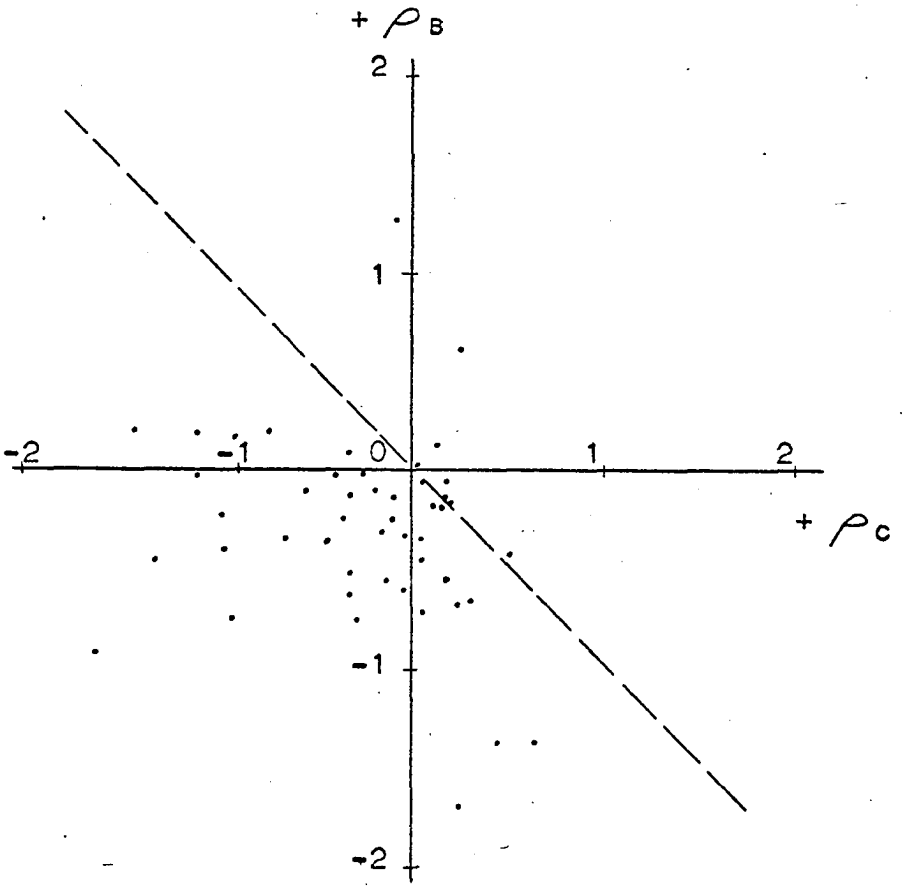

ILLUSTRATION 9. SCATTER DIAGRAM OF THE CONTINGENCY INDEX

WOULD PROVIDE LESS RETURN TO THE NATION'S ECONOMY THAN ORIGINALLY ANTICIPATED AS A RESULT OF THE INCREASED APPROPRIATIONS NECESSARY FOR THEIR CONSTRUCTION AND THE FEWER THAN ESTIMATED ACRES PLACED UNDER IRRIGATION.

ALSO, THIS REGION OF A NEGATIVE CONTINGENCY INDEX IMPLIES THAT APPROVAL WAS GIVEN TO THESE PROJECTS BASED UPON AN INFLATED BENEFIT-COST RATIO. THIS APPROVAL MIGHT HAVE RESULTED IN AN ALLOCATION OF RATIONED CAPITAL TO PROJECTS WHICH, IF ESTIMATES HAD BEEN ACCURATE, MIGHT NOT HAVE MET THE STANDARD OF JUSTIFICATION. IN FACT, THE MORE INFLATED THE BENEFIT-COST RATIO BECOMES, THE HIGHER WOULD BE THE LIKELIHOOD THAT A PROJECT WOULD BE ACCEPTED, FOR THE ERRONEOUS DECISION CRITERION COULD MAKE THE INVESTMENT APPEAR QUITE ATTRACTIVE TO THE DECISION-MAKER.

AS WAS DONE FOR THE COST AND BENEFIT CONTINGENCY INDICES, A CUMULATIVE DISTRIBUTION OF THE CONTINGENCY INDEX, ρ_{BC}, WAS PLOTTED, AS SHOWN IN ILLUSTRATION 10, PAGE 103. FROM THIS DISTRIBUTION A FREQUENCY DISTRIBUTION FOR ρ_{BC} WAS DERIVED, AS SHOWN IN ILLUSTRATION 11, PAGE 104. WHILE SUCH PLOTS OF THE FREQUENCY DISTRIBUTION WOULD NOT BE ABSOLUTELY NECESSARY IN THE APPLICATION OF THE CONTINGENCY INDEX PROCEDURES, A VISUAL REPRESENTATION OF COMPUTATIONAL RESULTS OFTEN PROVIDES ASSURANCE THAT NO DIFFICULTIES WOULD OCCUR IN THE ANALYSIS AS A RESULT OF A SKEWED, OR MULTIMODAL DISTRIBUTION.

WHILE SHOWING SOME SKEWNESS, THE SHAPE OF THE DISTRI-

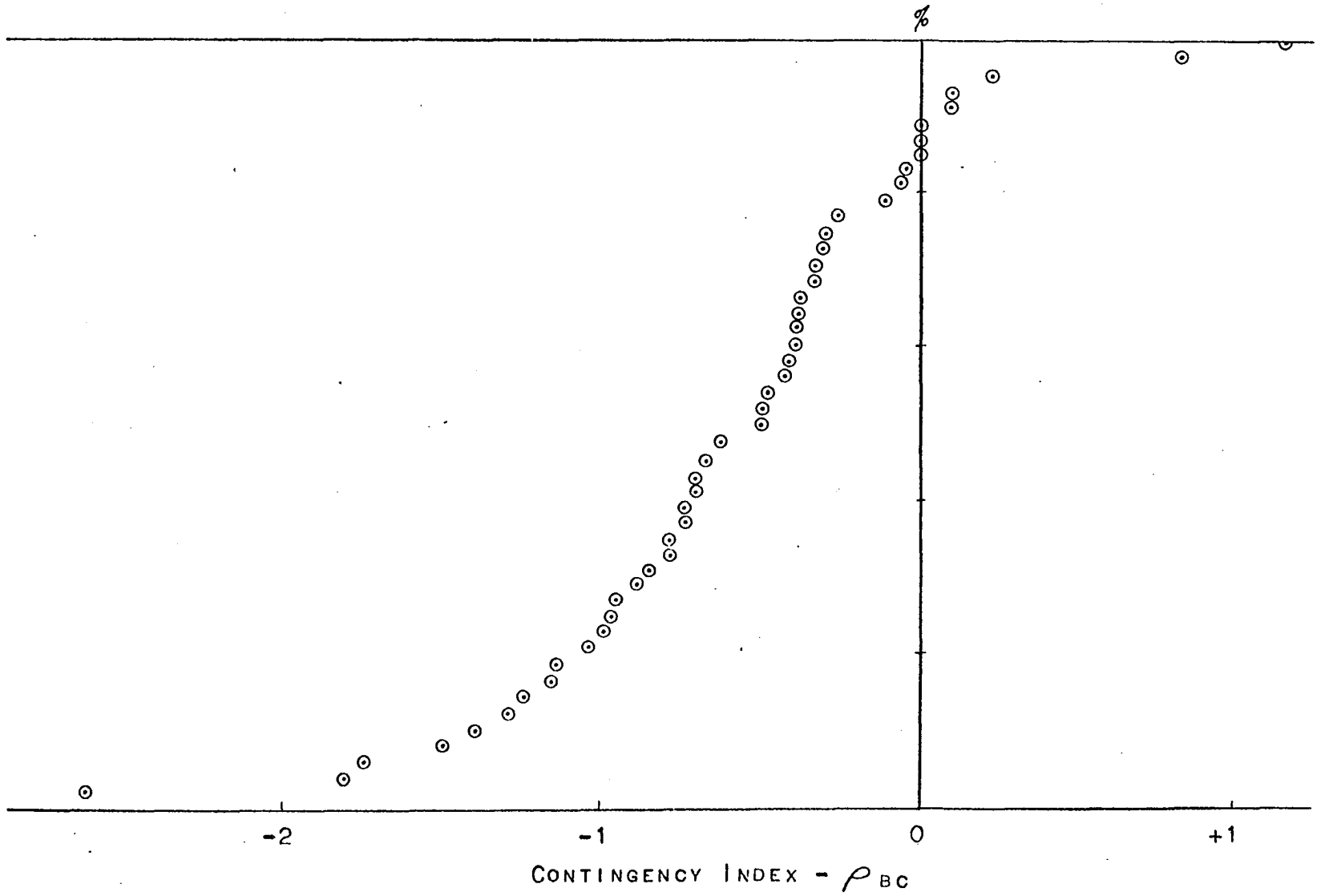

ILLUSTRATION 10. CUMULATIVE DISTRIBUTION OF THE CONTINGENCY INDEX, ρ_{BC}

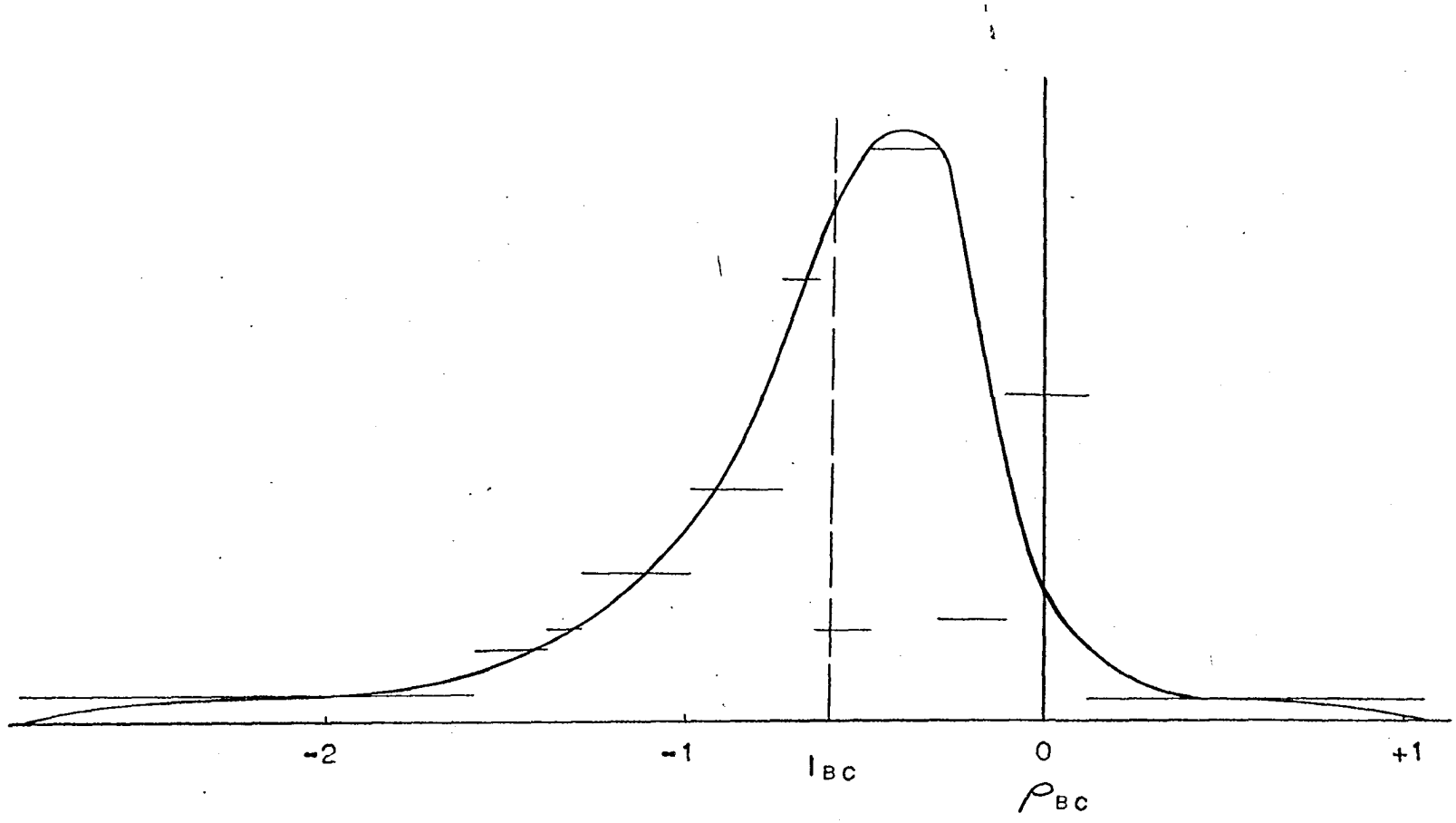

ILLUSTRATION 11. CONTINGENCY INDEX, ρ_{BC}, DENSITY FUNCTION

BUTION SHOWN IN ILLUSTRATION 11 WAS MORE NORMAL APPEARING THAN EITHER OF THE COST OR BENEFIT COMPONENT DISTRIBUTIONS. THIS TENDENCY TOWARD NORMALCY WOULD BE EXPECTED FROM ADDITIVE FACTORS, ANOTHER ADVANTAGE INHERENT TO THE TREATMENT OF BENEFITS AND COSTS WITH THE CONTINGENCY INDEX. SINCE BENEFITS AND COSTS WERE ASSUMED TO BE INDEPENDENT, THE MEAN AND VARIANCE OF THE CONTINGENCY INDEX DISTRIBUTION WOULD BE FOUND BY SUMMING THE EXPECTED VALUES AND THE VARIANCES OF THE BENEFIT CONTINGENCY INDEX DISTRIBUTION AND THE COST CONTINGENCY INDEX DISTRIBUTION. THUS, THE BENEFIT-COST RATIO HAS EXHIBITED LESS ACCURACY THAN EITHER OF ITS COMPONENTS AS SHOWN BY THE GREATER NEGATIVE EXPECTED VALUE OF ρ_{BC}. THE BENEFIT-COST DISTRIBUTION, REPRESENTED BY THE DISTRIBUTION OF ρ_{BC}, ALSO EXHIBITED A GREATER DISPERSION THAN THE DISTRIBUTION OF EITHER OF THE COMPONENT DISTRIBUTIONS. FINALLY, SINCE THE DISTRIBUTION OF ρ_{BC} HAD THE APPROXIMATE APPEARANCE OF A NORMAL DISTRIBUTION, NORMALITY WILL BE ASSUMED IN THIS ANALYSIS IN THE ESTABLISHMENT OF CONFIDENCE LIMITS.

ONE OF THE MOST IMPORTANT FUNCTIONS OF THE CONTINGENCY INDEX WOULD BE THAT OF MAKING INFERENCES ON THE APPROXIMATE CHARACTERISTICS OF A DISTRIBUTION OF POSSIBLE OUTCOMES OF AN ESTIMATED BENEFIT-COST RATIO. HOWEVER, BEFORE ANY INFERENCES WERE MADE, ASSURANCE WAS PROVIDED THAT NO TIME-RELATED TRENDS WERE PRESENT WHICH MIGHT PRODUCE ERRONEOUS CONCLUSIONS. THEREFORE, VALUES OF π_{C_T} WERE PLOTTED TO DETERMINE IF THE ESTIMATION ACCURACY HAD VARIED WITH TIME. THE TABULATED

VALUES OF π_{C_T} WERE SHOWN IN TABLE 6, PAGE 83, AND THE PLOT OF THESE VALUES VERSUS THE YEAR OF PROJECT AUTHORIZATION HAS BEEN SHOWN IN ILLUSTRATION 12, PAGE 107. WHILE NO CONCLUSIVE TREND WAS EVIDENT FROM THE PLOT FOR THE SAMPLE ANALYZED, THE POINTS DO SEEM TO INDICATE A DEFINITE IMPROVEMENT IN ESTIMATION ACCURACY OVER TIME. THIS IMPROVED ACCURACY WOULD BE EXPECTED AS THE ANALYSTS' EXPERIENCE INCREASED.[1] THE PLOT OF π_{B_T}, ILLUSTRATION 13, PAGE 108, SEEMS TO INDICATE THAT THE TREND OF BENEFIT ESTIMATION ACCURACY HAS BEEN DECREASING OVER TIME.[2] FINALLY, THE PLOT OF π_{BC_T} SHOWN IN ILLUSTRATION 14, PAGE 109, SEEMED TO INDICATE THAT THE DEVIATIONS IN THE ESTIMATED BENEFIT-COST RATIO HAVE REMAINED APPROXIMATELY CONSTANT WITH RESPECT TO TIME. SUCH A CONCLUSION WOULD BE EVIDENT FROM THE ADDITIVE NATURE OF THE COMPONENT INDICES, FOR AS THE ESTIMATION OF COSTS IMPROVED AND THE ESTIMATION OF BENEFITS WORSENED, THE NET RESULT WOULD BE A CONSTANT OVERALL EFFECT. WHILE THIS CONSTANT DEVIATION WAS, UNFORTUNATELY, IN THE REGION OF A NEGATIVE CONTINGENCY INDEX, THE CONSTANCY OF THE DEVIATION LEVEL OF π_{BC_T} WOULD SEEM TO IMPLY THAT, CETERIS PARIBUS,

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[1] COST DATA SECURED ON BUREAU OF RECLAMATION PROJECTS CONSTRUCTED AFTER WORLD WAR II, ESPECIALLY THOSE IN THE MISSOURI RIVER BASIN, SEEM TO INDICATE THAT THE ACCURACY HAS BEEN AGAIN DECREASING.

[2] SOME OF THIS DECREASE IN THE ESTIMATION ACCURACY OF THE SAMPLE OF BUREAU OF RECLAMATION DATA MAY BE ATTRIBUTAL TO PROJECT DEVELOPMENT WHICH WAS SLOWER THAN ANTICIPATED, POSSIBLY AS A RESULT OF WORLD WAR II; HOWEVER, EVIDENCE EXISTS THAT THE TREND EVIDENT IN ILLUSTRATION 13 IS A REAL TENDENCY TOWARD OVERESTIMATION.

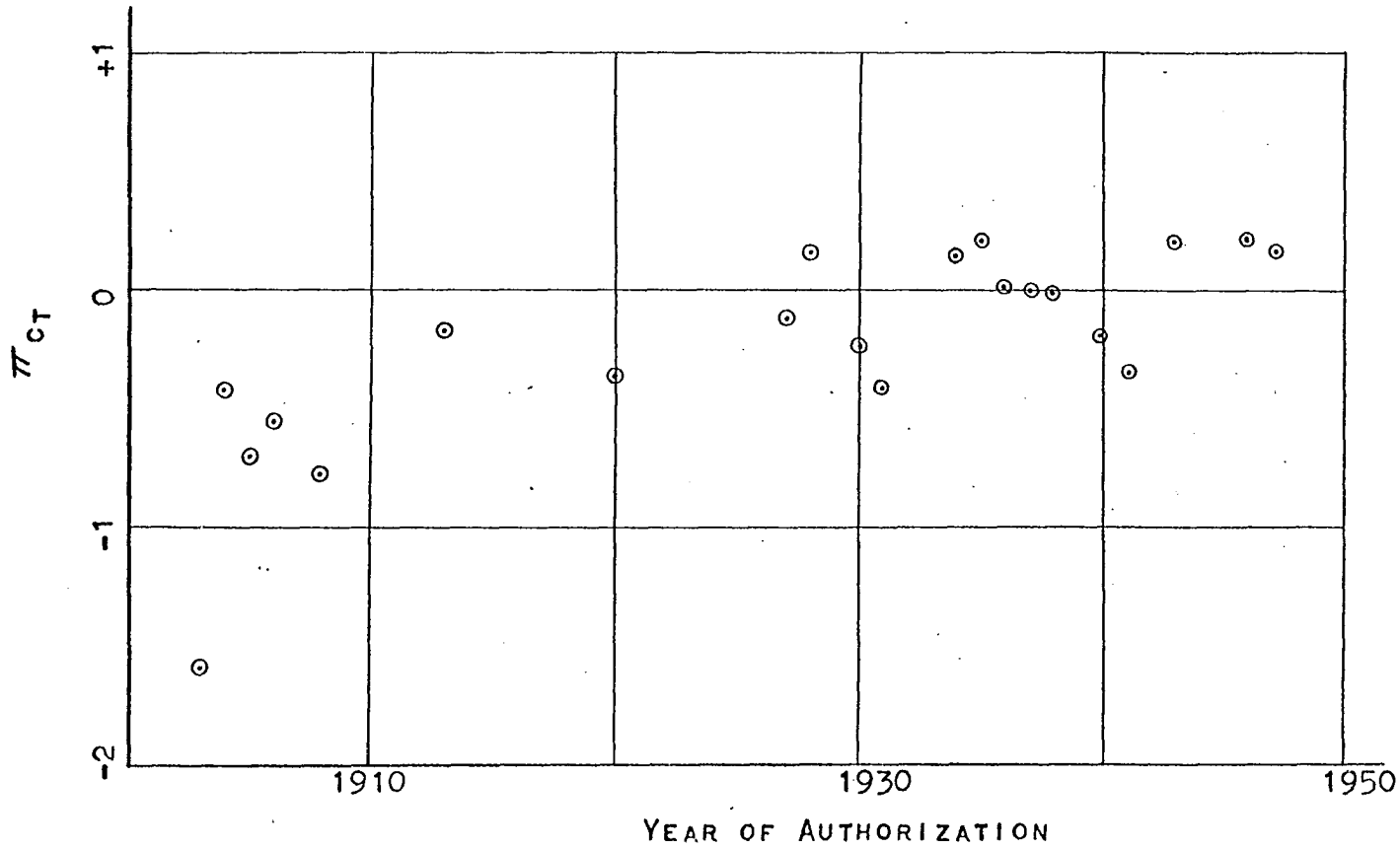

ILLUSTRATION 12. PLOT OF DEVIATIONS FROM ESTIMATED CONSTRUCTION COSTS AVERAGED BY YEAR OF AUTHORIZATION

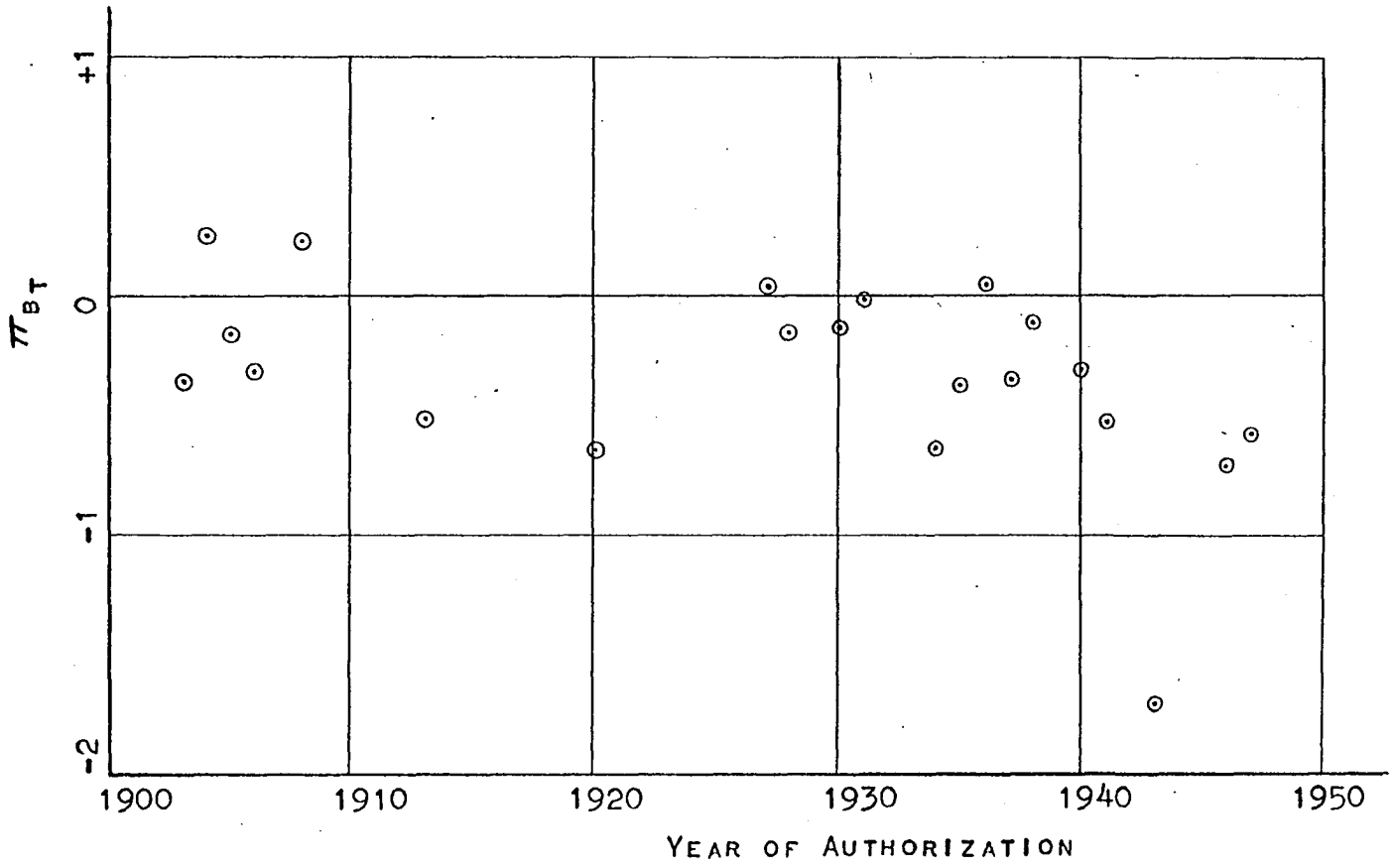

ILLUSTRATION 13. PLOT OF DEVIATIONS FROM ESTIMATES OF ACRES TO BE IRRIGATED AVERAGED BY YEAR OF AUTHORIZATION

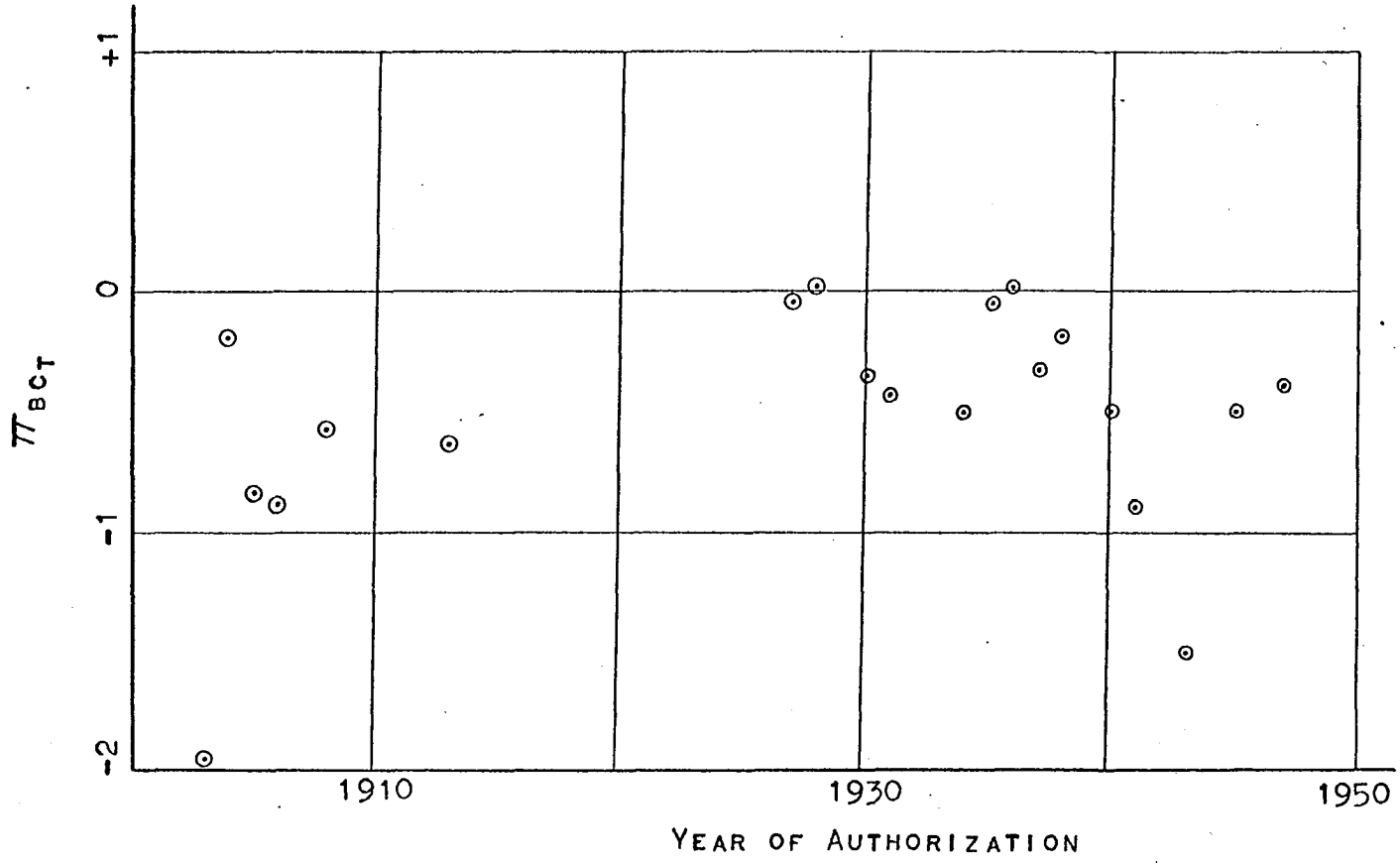

ILLUSTRATION 14. PLOT OF THE DEVIATIONS FROM THE ESTIMATED BENEFIT-COST RATIO AVERAGED BY YEAR OF AUTHORIZATION

ANY INFERENCES MADE ON FUTURE ESTIMATES BASED ON HISTOFICAL DATA WOULD BE VALID WITHIN REASONABLE LIMITS OF INDUCED ERROR.

IF A GROUP OF PROJECTS SELECTED FOR ANALYSIS WERE CONSIDERED TO BE A REPRESENTATIVE SAMPLE OF THE ENTIRE POPULATION OF THE TYPE OF GOVERNMENTAL CAPITAL EXPENDITURE UNDER CONSIDERATION, THEN INFERENCES MIGHT BE MADE REGARDING THE CHARACTERISTICS OF THE DISTRIBUTION OF POSSIBLE OUTCOMES OF THE ESTIMATES OF THE BENEFIT-COST RATIOS OF FUTURE PROPOSALS PRESENTED TO THE DECISION-MAKERS.[1] SINCE THE ASSUMPTION HAS BEEN MADE THAT THE SAMPLE USED IN THIS ANALYSIS WOULD BE A REPRESENTATIVE SAMPLE AND SINCE THE VALUES OF THE CONTINGENCY INDEX, ρ_{BC}, SEEM TO REMAIN FAIRLY CONSTANT WITH RESPECT TO TIME, AS INDICATED BY THE PLOT OF $\overline{\pi}_{BC_T}$ IN ILLUSTRATION 14, PAGE 109, THE EXPECTED VALUE OF THE CONTINGENCY INDEX FREQUENCY DISTRIBUTION, THE OBSERVED CONTINGENCY INDEX, I_{BC}, HAS BEEN ASSUMED TO APPLY TO DISTRIBUTIONS OF FUTURE ESTIMATES.

THE VALUE OF THE OBSERVED CONTINGENCY INDEX, I_{BC}, WOULD SERVE AS A CORRECTION FACTOR WHICH THE ANALYST COULD APPLY TO THE VALUE OF THE ESTIMATED BENEFIT-COST RATIO. THIS ADJUSTMENT WOULD BE ACCOMPLISHED BY TAKING THE NATURAL LOGARITHM OF THE ESTIMATED BENEFIT-COST RATIO, ADDING THE VALUE OF THE OBSERVED CONTINGENCY INDEX TO THIS LOGARITHM,

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[1]THE ASSUMPTION HERE WOULD BE THAT THE DISTRIBUTION OF DEVIATIONS FOR THE POPULATION WOULD BE THE SAME AS THE DISTRIBUTION FOR THE SAMPLE.

AND THEN TAKING THE ANTILOGARITHM OF THE COMBINED TOTAL TO CONVERT THE NUMBER TO AN ADJUSTED EXPECTED VALUE OF THE BENEFIT-COST RATIO OF THE PROPOSED CAPITAL EXPENDITURE.[1]

THE FUNCTION OF THIS CORRECTION FACTOR WOULD BE TO REMOVE ANY CONSISTENT ESTIMATION BIAS FROM THE BENEFIT-COST RATIO OF A PROPOSED EXPENDITURE BY ADJUSTING THE ESTIMATED VALUE OF THE BENEFIT-COST RATIO WITH THE OBSERVED CONTINGENCY INDEX FOUND FOR A SAMPLE OF PREVIOUS EXPENDITURES. IN OTHER WORDS, THIS ADJUSTMENT WOULD TRANSLATE THE EXPECTED VALUE OF THE DISTRIBUTION OF THE PROPOSED BENEFIT-COST RATIO TO ZERO. SUCH AN UNBIASED VALUE OF THE BENEFIT-COST RATIO SHOULD ENHANCE THE DECISION-MAKER'S KNOWLEDGE, FOR HE SHOULD BE PROVIDED A TRUE VALUE OF THE NET PUBLIC BENEFITS TO BE DERIVED FROM AN INVESTMENT AND THUS SHOULD BE ABLE TO ALLOCATE SCARCE CAPITAL RESOURCES MORE EFFECTIVELY.

THE FINAL STEPS IN THE CONTINGENCY INDEX ANALYSIS PROCEDURE OUTLINED IN TABLE 3, PAGE 69, STEPS 8 AND 9, WOULD BE THE ESTABLISHMENT OF A CONFIDENCE INTERVAL FROM THE VARIANCE OF THE DISTRIBUTION OF ρ_{BC} AND THE APPLICATION OF THIS CONFIDENCE INTERVAL TO THE VALUE OF THE BENEFIT-COST RATIO OF THE PROPOSED CAPITAL EXPENDITURE. THIS CONFIDENCE INTERVAL WOULD PROVIDE THE DECISION-MAKER WITH THE INFORMATION WHICH THIS STUDY CONTENDED WAS NECESSARY, INFORMATION

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[1] THIS CALCULATION MIGHT BE SUMMARIZED BY THE EQUATION:
$LN(Z_A) = LN(Z) + I_{BC}$;
WHERE Z_A = THE ADJUSTED VALUE OF THE BENEFIT-COST RATIO.

RELATING TO THE RANGE OF POSSIBLE OUTCOMES WITHIN WHICH THE BENEFIT-COST RATIO OF A PROPOSED INVESTMENT MIGHT FALL.

ASSUMING THAT THE DISTRIBUTION OF ρ_{BC} WAS NORMAL, A NINETY-FIVE PER CENT CONFIDENCE INTERVAL COULD BE ESTABLISHED USING THE ACCURACY INDEX, J_{BC}.[1] THIS RANGE WOULD BE FOUND BY ESTABLISHING A REGION OF TWO TIMES THE SQUARE ROOT OF J_{BC} ON EITHER SIDE OF THE ADJUSTED EXPECTED VALUE OF THE PROPOSED INVESTMENT.[2] ONE WOULD THEN BE NINETY-FIVE PER CENT CERTAIN THAT THE ACTUAL BENEFIT-COST RATIO OF A PROJECT WOULD FALL WITHIN THIS REGION.

NOW THAT THE COMPLETE PROCEDURE HAS BEEN DESCRIBED FOR USING THE CONTINGENCY INDEX IN THE ANALYSIS OF PAST DATA TO MAKE INFERENCES ON POSSIBLE OUTCOMES OF FUTURE ESTIMATES OF THE BENEFIT-COST RATIO, AN EXAMPLE OF THE APPLICATION OF THIS PROCEDURE WILL BE PROVIDED. THE VALUES OF THE OBSERVED CONTINGENCY INDEX, I_{BC}, AND THE ACCURACY INDEX, J_{BC}, SHOWN IN TABLE 7, PAGE 84, FOR THE SAMPLE OF BUREAU OF RECLAMATION

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[1] ONE MIGHT APPEAL TO THE CENTRAL LIMIT THEOREM FOR THIS ASSUMPTION.

[2] TO DETERMINE THE CONFIDENCE INTERVAL FOR A BENEFIT-COST RATIO OF A PROPOSED EXPENDITURE, TAKE THE NATURAL LOGARITHM OF THE ADJUSTED BENEFIT-COST RATIO, FOUND ABOVE; ADD AND SUBTRACT TWICE THE SQUARE ROOT OF THE ACCURACY INDEX, J_{BC}, PRODUCING TWO LOGARITHMIC VALUES; AND FIND THE ANTILOG OF THESE TWO VALUES TO PRODUCE THE UPPER AND LOWER CONFIDENCE LIMITS BETWEEN WHICH ONE MAY SAY THAT ONE HAS A NINETY-FIVE PER CENT CONFIDENCE OF THE ACTUAL BENEFIT-COST RATIO FALLING. THIS CALCULATION MAY BE SUMMARIZED BY THE EQUATION:

$$LN(CI) = LN(Z_A) \pm 2\sqrt{J_{BC}},$$

WHERE CI = THE NINETY-FIVE PER CENT CONFIDENCE INTERVAL.

PROJECTS, WERE USED TO ADJUST THE EXPECTED VALUES AND ESTABLISH CONFIDENCE INTERVALS FOR ALL PROJECTS SUBMITTED FOR APPROPRIATIONS IN THE 1957 FEDERAL BUDGET WHICH HAD A TOTAL COST EXCEEDING TWO MILLION DOLLARS AND FOR WHICH A BENEFIT-COST RATIO HAD BEEN DETERMINED.[1] A LISTING OF THESE PROJECTS, THEIR BENEFIT-COST RATIOS, THEIR TOTAL COST, THEIR ADJUSTED BENEFIT-COST RATIOS, Z_A, AND THEIR CONFIDENCE INTERVALS MAY BE FOUND IN TABLE 10, PAGE 114.

IF THE BENEFIT-COST RATIOS FOR THE PROJECTS IN TABLE 10 WERE ADJUSTED WITH THE OBSERVED CONTINGENCY INDEX, I_{BC}, THE RESULT, AS SUMMARIZED IN TABLE 11, PAGE 115, WOULD BE THAT THE BENEFIT-COST RATIOS WOULD DROP FROM A RANGE OF 5.7 TO 0.95 TO A RANGE OF 3.18 TO 0.53. RATHER THAN ONE PROJECT, REPRESENTING 0.2 PER CENT OF THE TOTAL FUNDS, WITH A BENEFIT-COST RATIO OF LESS THAN ONE, ELEVEN PROJECTS, REPRESENTING 20.8 PER CENT OF THE FUNDS, WOULD HAVE A BENEFIT-COST RATIO OF LESS THAN ONE. THUS, THE REMOVAL OF ESTIMATION BIAS FROM THESE SAMPLES WOULD RESULT IN THE DEFLATION OF THE BENEFIT-COST RATIOS PRESENTED TO THE DECISION-MAKER AND PROJECTS WHICH MIGHT HAVE ORIGINALLY APPEARED JUSTIFIED MIGHT NOT NOW BE ELIGIBLE TO RECEIVE FUNDS.

THE RANGE OF VALUES OF THE POSSIBLE OUTCOMES INDICATED

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[1] ONE SHOULD REALIZE THAT THE BENEFIT-COST RATIOS SHOWN IN THIS TABLE WERE CALCULATED ON THE BASIS OF TOTAL BENEFITS; THAT IS, THE BENEFIT-COST RATIOS INCLUDED DIRECT AND INDIRECT BENEFITS SO, ACCORDING TO MOST AUTHORS (14, 15, 23, 24, 28, 38, 44, 45), THE RATIOS WOULD BE INFLATED DUE TO THIS REASON ALSO.

TABLE 10. APPLICATION OF CONTINGENCY INDEX IN ADJUSTING BENEFIT-COST RATIOS OF PROJECTS SUBMITTED FOR APPROPRIATIONS IN 1957 FEDERAL BUDGET[A]

PROJECT[B]	BENEFIT-COST RATIO	TOTAL COST $ MILLION	ADJUSTED BENEFIT-COST RATIO	RANGE OF BENEFIT-COST RATIOS, 95% C I
SANTA MARIA, CALIF.	3.7	16.7	2.06	7.7 TO 0.55
SOLANO, CALIF.	3.8	51.0	2.14	7.9 TO 0.57
COLORADO-BIG THOMPSON	2.4	159.4	1.34	5.0 TO 0.36
MICHAND FLATS, ID.	2.55	4.7	1.42	5.3 TO 0.38
MINIDOKA, ID.	3.56	10.5	1.99	7.4 TO 0.53
PALISADES, ID.	2.55	62.6	1.42	5.3 TO 0.38
MIDDLE RIO GRANDE, N. M.	2.8	29.5	1.56	5.8 TO 0.42
WEBER BASIN, ID.	2.7	66.7	1.51	5.6 TO 0.41
COLUMBIA BASIN, WASH.	4.30	759.4	2.40	8.9 TO 0.64
YAKIMA-KENNEWICK DIV., WASH.	5.7	13.3	3.18	13.0 TO 0.85
EDEN, WYO.	1.27	7.5	0.71	2.6 TO 0.19
BOSTWICK DIV., NEB. & KAN.	1.51	48.6	0.84	3.1 TO 0.23
FRENCHMAN-CAMBRIDGE DIV., NEB.	1.33	68.2	0.74	2.7 TO 0.20
GLENDO UNIT, WYO.	1.19	42.6	0.66	2.5 TO 0.18
HANOVER BLUFF, WYO.	1.79	3.2	0.65	2.4 TO 0.18
HELENA VALLEY, MONT.	1.46	11.6	0.81	3.0 TO 0.22
KIRWIN, KAN.	1.02	18.5	0.57	2.1 TO 0.15
LOWER MARIAS, MONT.	2.08	64.9	1.16	4.3 TO 0.31
OWL CREEK, WYO.	0.95	2.6	0.53	2.0 TO 0.14
RAPID VALLEY, S. D.	1.95	9.0	1.09	4.0 TO 0.29
SARGENT UNIT, NEB.	1.07	14.5	0.60	2.2 TO 0.16
WEBSTER UNIT, KAN.	1.15	17.0	0.64	2.4 TO 0.17
YELLOW TAIL, MONT. & WYO.	1.50	93.2	0.84	3.1 TO 0.22

[A]SOURCE: 14, P. 276.

[B]AVAILABLE BENEFIT-COST RATIOS FOR PROJECTS EXCEEDING $2 MILLION.

TABLE 11. SUMMARY OF AFFECT OF CONTINGENCY INDEX ADJUSTMENT UPON THE BENEFIT-COST RATIO RANKING

RANGE OF BENEFIT-COST RATIOS	AS PRESENTED IN BUDGET			AFTER CONTINGENCY INDEX ADJUSTMENT		
	NUMBER OF PROJECTS	TOTAL COST $ MILLION	PER CENT OF TOTAL COST	NUMBER OF PROJECTS	TOTAL COST $ MILLION	PER CENT OF TOTAL COST
0 TO 0.99	1	2.6	0.2	11	327.5	20.8
1.00 TO 1.29	5	100.1	6.4	2	73.9	4.7
1.30 TO 1.59	4	221.6	14.1	5	322.9	20.5
1.60 TO 1.99	2	12.2	0.8	1	10.5	0.7
2.00 TO 2.99	6	387.8	24.6	3	827.1	52.5
3.00 TO 4.99	4	837.6	53.2	1	13.3	0.8
OVER 5.00	1	13.3	0.8	0	0	0

BY THE CONFIDENCE INTERVALS SHOWN IN TABLE 10 SHOULD ALSO PROVE BENEFICIAL TO THE DECISION-MAKER IN THE ALLOCATION OF SCARCE CAPITAL RESOURCES. WHILE IT IS TRUE THAT AN OUTCOME WHICH FELL WITHIN THE UPPER END OF THIS REGION WOULD APPEAR INVITING, THE LOWER END COULD BE FRIGHTENINGLY POOR. A RANGE OF POSSIBLE BENEFIT-COST RATIOS, ESTABLISHED BY CONFIDENCE LIMITS COULD PROVIDE THE DECISION-MAKER WITH SOME INTERESTING DISCUSSIONS ON THE DESIRABILITY OF SELECTED INVESTMENTS.

ONE ADDITIONAL NOTE ON THE CONTINGENCY INDEX ANALYSIS WOULD CONCERN THE HIGH DEVIATIONS FROM THE ESTIMATED VALUES OF THE COST OF OPERATING AND MAINTAINING RECLAMATION PROJECTS, AS SHOWN IN TABLE 6, PAGE 83, AT LEAST FOR THE PROJECTS WHERE ESTIMATES WERE AVAILABLE.

THE PERCENTAGE DEVIATION OF THE ACTUAL OPERATION AND MAINTENANCE COSTS FROM THE ESTIMATED OPERATION AND MAINTENANCE COSTS, R_M, WAS CALCULATED IN ORDER TO SHOW THE LARGE DEVIATIONS POSSIBLE IN THE COMPONENT COSTS OF CAPITAL EXPENDITURES WHICH ADD TO FORM THE COST COMPONENT OF THE BENEFIT-COST RATIO. WHILE NO ANALYSIS WAS MADE OF THE DISTRIBUTION ASSOCIATED WITH R_M BECAUSE OF THE LACK OF SUFFICIENT DATA TO FORM A REPRESENTATIVE SAMPLE, THE VALUES SHOWN IN TABLE 4, PAGE 73, ILLUSTRATE THAT THE PROBABLE VARIANCE OF A DISTRIBUTION OF R_M WOULD BE LARGE AND WOULD TEND TO CONTRIBUTE TO A LARGE VARIANCE FOR THE DISTRIBUTION OF THE TOTAL COST COMPONENT.

Application of the Contingency Index in Sensitivity Analysis

If the decision-maker is to make a proper allocation of rationed capital among competing investments, then information should be at his disposal concerning variations in the net public benefit, as expressed by the benefit-cost ratio, produced by variations in sensitive components incorporated into the ratio.[1] Thus, when relatively small variations of a factor effect a decision concerning an expenditure, the factor would be a sensitive factor and extreme care should be used in obtaining and analyzing the data used in formulating its estimate. Conversely, an element which could be varied over a wide range without effecting the final decision on whether or not to accept a proposal would be an insensitive factor. It follows that the analysis of the effect upon the determination of the final outcome of variations in sensitive factors is known as sensitivity analysis.

Sensitivity analysis becomes important when one realizes the vague nature of many of the estimates of benefits and costs which have been used in the justification of governmental capital expenditures. An example of the inclusive nature of the data often presented to the decision-maker may be found in the following quotation.

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[1] "Sensitivity refers to the relative magnitude of the change in one or more elements of an engineering economy problem that will reverse a decision among alternatives." (22, p. 240)

> MANY OF THE DATA HEREIN ARE THE RESULT OF RECONNAISSANCE INVESTIGATION. PRIOR TO CONSTRUCTION OF THE PROJECT, DETAILED SURVEYS WOULD BE REQUIRED FOR FINAL LOCATION OF THE DAM AND AQUEDUCT SYSTEM AND IT WOULD BE NECESSARY TO FURTHER INVESTIGATE FOUNDATION CONDITIONS AT THE DAM SITE WITH DRILL HOLES AND MATERIALS TESTING. THE WATER SUPPLY AND SEDIMENTATION STUDIES AND SPILLWAY REQUIREMENTS WOULD BE REFINED, AND ADDITIONAL INFORMATION OF THE QUALITY OF CANADIAN RIVER FLOW IS REQUIRED. AS A RESULT OF THE FOREGOING, ALL COST ESTIMATES WOULD BE SUBJECT TO REFINEMENT. ... ON THE BASIS OF EXPRESSION OF INTERESTS OF THE CITIES IN PARTICIPATION IN THE FINAL PROJECT AND THE FURTHER DETAILED ENGINEERING STUDIES LISTED ABOVE, FINAL SELECTION OF THE RESERVOIR SITE AND PIPELINE ALINEMENT WOULD BE MADE. (101, P. 27)

NOT ONLY HAVE THE ESTIMATES USED IN PROJECT JUSTIFICATION BEEN SUBJECT TO VARIATION BECAUSE OF A LACK OF DEFINITE INVESTMENT IMPLEMENTATION PLANS, BUT GOVERNMENTAL EXPENDITURE PROPOSALS HAVE OFTEN BEEN EXPANDED IN SCOPE UNTIL THEIR BENEFIT-COST RATIOS APPROACH THE MINIMUM ALLOWABLE LEVEL.

> ...[I]T IS SIGNIFICANT THAT BY FAR THE LARGEST CONCENTRATION OF PROJECTS, BOTH IN ABSOLUTE NUMBER AND IN FEDERAL FUNDS COMMITTED IS LOCATED AT THE VERY BOTTOM END OF THE DISTRIBUTION--THE RANGE WHICH EVEN UNDER THE MOST LIBERAL INTERPRETATION, IS MARGINAL. (24, PP. 15-16)

THUS, VARIATIONS IN SENSITIVE FACTORS MIGHT RESULT IN A COST TO THE NATION WHICH MIGHT BE GREATER THAN THE VALUE OF THE BENEFITS WHICH THE PROJECT WAS EXPECTED TO YIELD.

REFERRING TO EQUATION 1, PAGE 11, IT IS EVIDENT THAT THE BENEFIT-COST RATIO MIGHT BE SENSITIVE TO VARIATIONS IN THE ESTIMATES OF BENEFITS AND COSTS, IN THE GIVEN CONSTANTS, IN THE DISCOUNT RATE, AND IN THE AVERAGE SERVICE LIFE. THE

POSSIBLE SENSITIVITY OF PROPOSAL ACCEPTABILITY TO VARIATIONS IN THE DISCOUNT RATE AND AVERAGE SERVICE LIFE HAVE BEEN DISCUSSED, FOR EXAMPLE, BY HAVEMAN (24), ECKSTEIN (15), AND PROXMIRE (63). ALL OF THESE WRITERS HAVE SHOWN THAT INCREASES IN THE DISCOUNT RATE TEND TO REDUCE THE BENEFIT-COST RATIO OF THE MAJORITY OF PROJECTS BELOW THE SHIBBOLETH LEVEL OF ONE. FOR EXAMPLE, IN 147 PROJECTS CONSTRUCTED BY THE CORPS OF ENGINEERS IN TEN SOUTHERN STATES, HAVEMAN (24) FOUND THAT FORTY-FIVE OF THESE PROJECTS, INVOLVING 41.92 PER CENT OF THE FEDERAL FUNDS COMMITTED, WERE REJECTED BY EACH OF FIVE TEST CRITERIA, INVOLVING VARIATIONS IN THE DISCOUNT RATE AND THE AVERAGE SERVICE LIFE.[1]

WHILE SENSITIVITY TO VARIATIONS IN THE AVERAGE LIFE AND THE DISCOUNT RATE HAVE BEEN DISCUSSED, CONSIDERATION HAS NOT BEEN GIVEN TO THE POSSIBLE SENSITIVITY OF PROJECT JUSTIFICATION TO VARIATIONS IN THE ESTIMATES OF THE COMPONENTS WHICH MAKE UP THE BENEFIT-COST RATIO. THE CONTINGENCY INDICES ARE SUITED FOR USE IN A SENSITIVITY ANALYSIS OF THESE COMPONENTS. NOT ONLY WOULD THE INDICES MEASURE THE EFFECT OF POSSIBLE VARIATIONS IN THE COST OR BENEFIT COMPONENTS FROM VARIATIONS IN THEIR RESPECTIVE FACTORS, BUT DUE TO THE ADDITIVE NATURE OF THESE INDICES, SHOWN IN EQUATION 15, PAGE 62, A SENSITIVITY ANALYSIS WOULD ALSO SHOW THE EFFECT OF COMPONENT SENSITIVITY UPON THE BENEFIT-COST RATIO.

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[1]FOR A DISCUSSION OF THESE FIVE TEST CRITERIA, SEE HAVEMAN (24, PP. 11-12).

A SENSITIVITY ANALYSIS UTILIZING THE CONTINGENCY INDEX WOULD BE IMPLEMENTED BY FIRST FINDING THE POSSIBLE DEVIATION OF A SENSITIVE FACTOR. THEN, BY EITHER SIMULATING POSSIBLE OUTCOMES OR TAKING THE EXTREMES OF THE EXPECTED VARIATION IN A PARTICULAR COMPONENT, THE COST OR BENEFIT CONTINGENCY INDEX MAY BE FOUND FOR THE COMPONENT. THE CONTINGENCY INDEX ρ_{BC} WOULD THEN BE THE SUM OF THE NEW ρ_B AND ρ_C. IN THIS WAY THE DEVIATIONS OF SENSITIVE FACTORS COULD BE RELATED TO POSSIBLE DEVIATIONS IN THE BENEFIT-COST RATIO. THE ABILITY OF THE CONTINGENCY INDEX TO ANALYZE POSSIBLE VARIATIONS IN COMBINATIONS OF SENSITIVE FACTORS WOULD BE ESPECIALLY USEFUL. THUS, SENSITIVITY TESTING WOULD SHOW THE EFFECT OF VARIATIONS IN SENSITIVE COMPONENTS UPON THE BENEFIT-COST RATIO DISTRIBUTION AND WOULD PROVIDE AN INDICATION OF WHAT ELEMENTS WOULD NEED CLOSE INSPECTION AND CONTROL; THAT IS, THOSE ELEMENTS IN WHICH SLIGHT VARIATIONS FROM THE EXPECTED VALUES MIGHT CHANGE THE PROJECT FEASIBILITY. EVEN A FEW SUCH CALCULATIONS WOULD PROVIDE THE DECISION-MAKER WITH MORE INFORMATION ON FACTORS WHOSE UNCERTAIN OUTCOME MIGHT PROVE SIGNIFICANT THAN HAS BEEN PROVIDED IN THE PAST, AT A COST FAR LESS THAN WOULD BE THE COST OF BUILDING A PROJECT WHOSE POSSIBLE OUTCOME MIGHT PROVE UNFAVORABLE TO THE NATIONAL ECONOMY.

DISTRIBUTION RECOGNITION THROUGH MULTIVALUED ESTIMATES

IN BENEFIT-COST ANALYSIS THE POSSIBILITY OF DETERMINING THE PROBABILITY DISTRIBUTION REPRESENTING THE POSSIBLE OUTCOMES

ASSOCIATED WITH ESTIMATES OF BENEFIT AND COST COMPONENTS USING THE CONTINGENCY INDEX ANALYSIS MAY BE REMOTE DUE TO THE LACK OF OR INAPPROPRIATENESS OF HISTORICAL DATA. A METHOD OF PROVIDING AN APPROXIMATE PROBABILITY DISTRIBUTION FOR ESTIMATES OF COSTS AND BENEFITS WHICH DOES NOT RELY UPON PAST ESTIMATES HAS BEEN OUTLINED IN THIS SECTION AND DEMONSTRATED IN APPENDIX C. THIS METHOD HAS BEEN AN ADAPTATION OF THE THREE ESTIMATE TECHNIQUES USED FOR PERT TIME SCHEDULING.[1] WHILE THIS TECHNIQUE HAS BEEN USED SUCCESSFULLY FOR SCHEDULING OPERATIONS, IT HAS NOT BEEN APPLIED TO BENEFIT-COST ESTIMATION.

IN APPLYING THE TECHNIQUE OF MULTIVALUED ESTIMATION TO BENEFIT-COST ANALYSIS, THREE ESTIMATES WOULD BE MADE FOR EACH ELEMENT OF COST AND BENEFIT. THE USE OF THREE ESTIMATES WOULD ALLOW THE ANALYST TO EXPRESS HIS FEELINGS ABOUT A REASONABLE RANGE OF OUTCOMES FOR EACH ESTIMATED FACTOR. THIS RANGE OF ESTIMATED VALUES SHOULD NOT BE CONSTRAINED BY PRECONCEIVED BUDGETS OR INFLATED IN ORDER TO JUSTIFY A PROJECT, FOR SUCH ACTIONS WOULD NULLIFY ONE OF THE MAJOR ADVANTAGES OF MULTIVALUED ESTIMATION, PROVIDING FACTUAL DOLLAR VALUES WITH REALISTIC VARIATIONS, SPECIFICALLY IDENTIFIABLE FOR INDEPENDENT FACTORS. DUE TO THE DIFFICULTY OF EXPRESSING SUCH ESTIMATED VALUES IN TERMS OF ABSOLUTE RELATIONSHIPS, THE ESTIMATES WOULD BE EXPRESSED IN TERMS OF LIKELIHOOD.

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[1]PERT IS AN ABBREVIATION FOR PROGRAM EVALUATION AND REVIEW TECHNIQUE.

As mentioned previously, when a single-valued estimate is made, the estimate often represents the most likely occurrence, that is, the value which would occur most frequently if the analysis were repeated a number of times under exactly the same conditions without additional knowledge. This modal value or most likely estimate, M, will be the first of the three estimates necessary to implement this technique.

The second estimate to be made would be the most favorable estimate, A. While this value would be obtainable, it probably would occur only one time in one hundred, if the component were to be duplicated under identitical conditions.

The final estimate to be made would be the least favorable estimate, B. Again, this estimate would have a hundred to one chance of being exceeded, and it should reflect the possibility of uncertain occurrences such as initial failure, technological change, or estimation errors arising from incomplete knowledge. Acts of God would not be considered in making these estimates. A distribution showing these three estimates may be found in illustration 15, page 123.

The determination of the most favorable and least favorable estimates would be made as carefully as possible, for realistic, independent estimates for each factor are critical in this technique. The estimates must not be of a distorted magnitude or warped to cover any conceivable

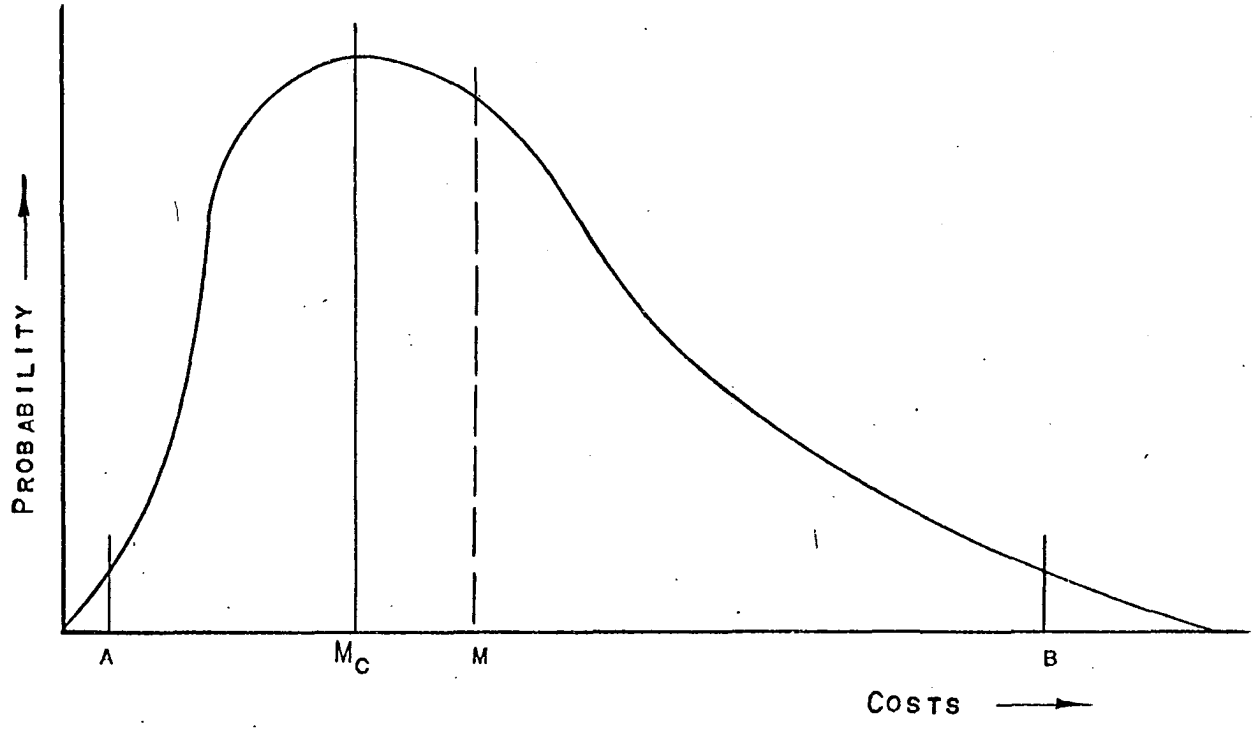

ILLUSTRATION 15. A TYPICAL PROBABILITY DISTRIBUTION ASSOCIATED WITH ESTIMATED COSTS, SHOWING THE THREE COST ESTIMATES

ADVERSITY; RATHER TOTALLY UNFORESEEN CIRCUMSTANCES SHOULD BE ACCOUNTED FOR BY CHANGES IN THE ORIGINAL ESTIMATES. IN ADDITION TO PROVIDING THE DECISION-MAKER WITH INFORMATION CONCERNING THE BEST AND WORST OUTCOMES WHICH MIGHT BE EXPECTED FROM A PROPOSAL, THE MULTIVALUED ESTIMATES ALSO SHOULD REDUCE THE TENDENCY TO COMPENSATE FOR ADVERSITIES BY INCLUDING SAFETY ALLOWANCES IN THE ESTIMATES OF THE SINGLE EXPECTED OUTCOME, ALLOWANCES WHICH MAY INTRODUCE A BIAS INTO THE DECISION CRITERION.

AFTER THE THREE ESTIMATES OF THE COMPONENT COSTS AND BENEFITS HAVE BEEN MADE, THESE ESTIMATES WOULD THEN BE USED TO FIND AN EXPECTED VALUE OF A DISTRIBUTION ASSUMED TO REPRESENT A DISTRIBUTION OF POSSIBLE OUTCOMES. IF ONE SUSPECTED THAT THE POSSIBLE OUTCOMES OF THE BENEFIT AND COST COMPONENTS MIGHT BE REPRESENTED BY A BETA DISTRIBUTION, THEN THE EXPECTED VALUE, E, OF THE DISTRIBUTION WOULD BE APPROXIMATED BY:

$$E = \frac{A + 4M + B}{6} .^{1} \qquad (31)$$

THIS EXPECTED VALUE WOULD LIE TO THE PESSIMISTIC SIDE OF THE MODE AND THUS WOULD PROVIDE AN ADJUSTMENT COMPARABLE TO THE CERTAINTY EQUIVALENT. EQUATION 31 ALSO WEIGHTS THE MODAL ESTIMATE TO A HIGH DEGREE; HOWEVER, THE BEST ESTIMATE OF THE MOST LIKELY OCCURRENCE SHOULD PROBABLY BE GIVEN THIS EXTRA

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[1] FOR A DISCUSSION OF THE ERROR ASSOCIATED WITH THE ASSUMPTIONS CONCERNING THE CHOICE OF A PARTICULAR DISTRIBUTION, SEE MACCRIMMON AND RYAVEC (41, P. 20).

CONSIDERATION, ESPECIALLY IN LIGHT OF THE PROMINENCE OF THE MODE IN ILLUSTRATION 6, PAGE 96, AND ILLUSTRATION 8, PAGE 99.

THE STANDARD DEVIATION, σ, OF THE ASSUMED DISTRIBUTION OF BENEFITS OR COSTS MIGHT BE APPROXIMATED BY EQUATION 32 AS FOLLOWS:

$$\sigma = \frac{B - A}{6} . \qquad (32)$$

SINCE THE ESTIMATES OF COSTS AND BENEFITS WERE ASSUMED TO BE INDEPENDENT, THE TOTAL VARIANCE ASSOCIATED WITH EACH OF THESE COMPONENTS WOULD SIMPLY BE THE SUM OF THE INDIVIDUAL VARIANCES OF EACH ESTIMATED FACTOR, WHERE THE VARIANCE, σ^2, WOULD BE THE SQUARE OF THE STANDARD DEVIATION, σ. THUS, AN APPROXIMATE NINETY-FIVE PER CENT CONFIDENCE INTERVAL MIGHT BE ESTABLISHED BY FINDING A 2σ RANGE ON EITHER SIDE OF THE ESTIMATED EXPECTED VALUE OF THE BENEFIT-COST RATIO USING THE METHOD DESCRIBED IN APPENDIX C.

A USEFUL PROPERTY OF THE PROBABILITY DISTRIBUTION CURVE, FOUND EITHER THROUGH THE CONTINGENCY INDEX ANALYSIS OR MULTIVALUED ESTIMATES, WOULD BE THAT THE AREA UNDER THE CURVE TO THE LEFT OF A GIVEN POINT WOULD PROVIDE A MEASURE OF THE PROBABILITY THAT THE ACTUAL VALUE OF COSTS OR BENEFITS WOULD BE EQUAL TO OR LESS THAN THE VALUE IN QUESTION. THESE PROBABILITIES WOULD PROVIDE A LINK BETWEEN THE FEASIBILITY ANALYSIS AND THE CONSTRUCTION COST CONTROL. THUS, THE PROJECT SUPERVISOR MIGHT ASCERTAIN AT AN EARLY DATE THE PROBABILITY OF A PROJECT BEING COMPLETED WITHIN THE

ESTABLISHED COST LIMITATIONS. IF THE PROBABILITY OF EXCEEDING THE BUDGETARY CONSTRAINTS BECAME LARGE, THEN APPROPRIATE ACTION MIGHT BE TAKEN AT SOME POINT IN TIME EARLY ENOUGH TO INITIATE EFFECTIVE CORRECTIVE ACTION.

THE USE OF EITHER MULTIVALUED ESTIMATES OR CONTINGENCY INDEX ANALYSIS WOULD THEN PROVIDE THE ANALYST WITH AN APPROXIMATE PROBABILITY DISTRIBUTION FROM WHICH TO DETERMINE AN EXPECTED VALUE REPRESENTING A COST OR BENEFIT COMPONENT AND THE VARIANCE ASSOCIATED WITH THIS EXPECTED VALUE. THE COMPONENT'S EXPECTED VALUES AND VARIANCES COULD THEN BE SUMMED IN ORDER TO FORM AN AGGREGATE EXPECTED VALUE AND VARIANCE FOR THE PROJECT BENEFIT-COST RATIO. WITH THIS INFORMATION THE DECISION-MAKER SHOULD BE ABLE TO MAKE A MORE COMPREHENSIVE CHOICE OF WHETHER OR NOT TO AUTHORIZE A PARTICULAR PROPOSAL AND COMMIT FUNDS TO ITS CONSTRUCTION.

CONCLUSIONS

> BEFORE CONGRESS [OR ANY GOVERNMENTAL DECISION-MAKER] AUTHORIZES AN IMPROVEMENT WORK, ..., IT [HE] SHOULD HAVE AVAILABLE AS REALISTIC AN ESTIMATE AS POSSIBLE OF THE PROBABLE COST IN ENERGY, MATERIALS AND MONEY. (112, P. 52)

THE SOUNDNESS OF THE FORMULATION OF THE JUSTIFICATION FOR A PROPOSED CAPITAL EXPENDITURE SHOULD DEPEND, IN PART, UPON THE RECOGNITION OF THE DISTRIBUTION OF POSSIBLE OUTCOMES ASSOCIATED WITH THE ESTIMATE OF THE BENEFIT-COST RATIO. THIS DISTRIBUTION WOULD REFLECT THE DEGREE OF UNCERTAINTY ASSOCIATED WITH PREDICTED VALUES OF THE MEASURE OF THE NET ECONOMIC BENEFIT WHICH THE NATION WOULD DERIVE FROM AN INVESTMENT. THUS, IT WAS THE CONTENTION OF THIS STUDY THAT THE RECOGNITION OF THE DISTRIBUTION ASSOCIATED WITH ESTIMATES OF COSTS AND BENEFITS OF PROPOSED CAPITAL EXPENDITURES WAS IMPORTANT IF THE DECISION-MAKER WERE TO HAVE ADEQUATE KNOWLEDGE WITH WHICH TO ALLOCATE RATIONED CAPITAL AMONG COMPETING PROPOSALS.

RECOGNITION OF THE DISTRIBUTION ASSOCIATED WITH ESTIMATES OF BENEFITS AND COSTS COULD BE ACCOMPLISHED BY EITHER OF THE TWO METHODS PROPOSED IN THIS STUDY. THE FIRST METHOD, THE CONTINGENCY INDEX ANALYSIS, WOULD PROVIDE A PROCEDURE FOR RECOGNIZING THE DISTRIBUTION OF BENEFIT-COST RATIO ESTIMATES OF PROPOSED EXPENDITURES BY ANALYZING THE DEVIATIONS FROM THE ESTIMATES EXHIBITED BY HISTORICAL DATA. THIS PROCEDURE WOULD RESULT IN THE DETERMINATION OF THE DISTRIBUTION CHARACTERISTICS OF PROPOSAL ESTIMATES WITH A MINIMUM NUMBER OF NECESSARY

ASSUMPTIONS. THE APPLICATION OF THE CONTINGENCY INDEX METHOD IN THIS INVESTIGATION SHOWED THAT THE BENEFIT-COST RATIOS ESTIMATED FOR PREVIOUS PROJECTS HAD BEEN INFLATED. THUS, AN ADJUSTMENT OF THE BENEFIT-COST RATIO OF PROPOSED PROJECTS WOULD TEND TO NEUTRALIZE ANY ESTIMATION BIAS FOUND IN THE EXPECTED VALUE OF THE BENEFIT-COST RATIO. THIS ADJUSTMENT WOULD PROVIDE THE DECISION-MAKER WITH A MUCH MORE REALISTIC ESTIMATE OF THE NET BENEFIT ACCRUING TO THE PUBLIC FROM ITS INVESTMENT.

IN ADDITION TO PROVIDING AN UNBIASED ESTIMATE OF THE BENEFIT-COST RATIO FOR A PROPOSED CAPITAL EXPENDITURE, THE CONTINGENCY INDEX ANALYSIS ALSO FURNISHED THE VARIANCE OF THE DISTRIBUTION OF POSSIBLE FUTURE OUTCOMES. THIS VARIANCE WAS USED TO ESTABLISH A CONFIDENCE INTERVAL ABOUT THE ADJUSTED EXPECTED VALUE. THEREFORE, THE TEST OF THE PROPOSED METHOD WAS NOT ONLY ABLE TO SHOW THAT CONSIDERABLE INFLATION HAD RESULTED IN THE ESTIMATED BENEFIT-COST RATIOS, BUT ALSO THAT THE CONFIDENCE INTERVAL ESTABLISHED FOR THE GROUP OF PROPOSED BENEFIT-COST RATIOS EMBRACED A LARGE RANGE OF VALUES, THE LOWER END OF WHICH WOULD PROBABLY PROVE TO BE HIGHLY UNSATISFACTORY.

IF HISTORICAL DATA WERE UNAVAILABLE OR IF THE DATA WERE SUCH THAT LITTLE RELIABILITY MIGHT BE PLACED UPON INFERENCES MADE FROM THESE DATA, THE DISTRIBUTION OF OUTCOMES COULD BE RECOGNIZED BY THE SECOND METHOD PROPOSED, THE USE OF MULTI-VALUED ESTIMATES. THIS METHOD COULD INTRODUCE A GREATER ERROR

INTO THE ANALYSIS THROUGH DISTRIBUTION ASSUMPTIONS THAN WOULD BE THE CASE WITH THE CONTINGENCY INDEX ANALYSIS; HOWEVER, THE MEAN AND VARIANCE OF A POSSIBLE DISTRIBUTION OF OUTCOMES COULD BE DETERMINED FROM THE COMPONENT ESTIMATES OF BENEFITS AND COSTS WITHOUT ANY REFERENCE TO PAST ESTIMATION PERFORMANCE.

THIS RECOGNITION OF THE DISTRIBUTION OF POSSIBLE OUTCOMES OF PROPOSED CAPITAL EXPENDITURES SHOULD ENHANCE THE DECISION-MAKERS' UNDERSTANDING OF THE POSSIBLE RETURN FROM AN INVESTMENT AND THE MAGNITUDE OF THE RISK AND UNCERTAINTY WHICH MIGHT BE ENCOUNTERED. THE INDICATION OF BOTH THE TRUE RETURN AND THE RANGE OF POSSIBLE RETURNS TO BE EXPECTED FROM AN INVESTMENT SHOULD BE AN AID TO THE DECISION-MAKER, FOR LITTLE INDICATION HAS BEEN PROVIDED OF THE EFFECT OF DEVIATIONS FROM THE ESTIMATED EXPECTED VALUES UPON THE ECONOMIC JUSTIFICATION OF A PROJECT.

> [W]HILE ALL OF THIS WORK WAS REPORTED AS ECONOMICALLY JUSTIFIED AT THE TIME OF ITS ORIGINAL CONSIDERATION BY CONGRESS, THE EFFECTS OF THE COST INCREASES [AND BENEFIT DECREASES] UPON ECONOMIC JUSTIFICATION ARE NOT KNOWN... (112, P. 17)

THUS, THE USE OF THE CONTINGENCY INDEX SHOULD PROVIDE INFORMATION ON THE AFFECTS OF THESE DEVIATIONS.

THE CONSTANT TREND OVER TIME OF THE NEGATIVE CONTINGENCY INDEX SHOWN IN THE SAMPLE ANALYZED IN THIS STUDY MIGHT IMPLY THAT PROPOSALS PRESENTED TO GOVERNMENTAL DECISION-MAKERS HAVE BEEN CHARACTERIZED BY THE OVERESTIMATION OF BENEFITS AND THE UNDERESTIMATION OF COSTS. THEREFORE, ONE MIGHT CONCLUDE

THAT DECISION-MAKERS HAVE RECEIVED NOT ONLY INADEQUATE INFORMATION UPON WHICH TO BASE THEIR DECISIONS, BUT ALSO INFORMATION WHICH WAS ACTUALLY BIASED AND INACCURATE.

> ESTIMATES OF THIS CHARACTER FURNISH AN AIR OF AUTHENTICITY TO A REPORT BUT ARE WORSE THAN MEANINGLESS. THEY HAVE NO REAL VALIDITY AND YET THE ABSENCE OF SUPPORTING DATA PREVENTS ADEQUATE INDEPENDENT ANALYSIS. CONGRESS IS THEN MISLED INTO TAKING ACTION ON THE BASIS OF DECEPTIVE COMPUTATIONS. (112, P. 17)

AN INTERESTING EXTENSION OF THIS RESEARCH MIGHT BE TO EXPAND THE APPLICATION OF THE CONTINGENCY INDEX TO OTHER FEDERAL CAPITAL EXPENDITURES, SUCH AS NAVIGATION OR FLOOD CONTROL PROJECTS CONSTRUCTED BY THE CORPS OF ENGINEERS OR HIGHWAY CONSTRUCTION OF THE VARIOUS STATES, TO DETERMINE THE POSSIBLE RANGE OF OUTCOMES AND THE TRUE BENEFIT-COST RATIO TO BE EXPECTED FOR THESE INVESTMENTS. IN ADDITION ONE MIGHT WISH TO KEEP THIS ANALYSIS OF RECLAMATION PROJECTS CURRENT IN ORDER TO TEST FOR POSSIBLE CHANGES IN TRENDS OF ESTIMATION ACCURACY. AN APPLICATION OF THE CONTINGENCY INDEX TO PROJECTS AUTHORIZED IN THE LAST DECADE MIGHT BE ESPECIALLY INTERESTING, FOR FAIRLY DETAILED ECONOMIC ANALYSES WERE MADE FOR THESE PROJECTS, AND THEREFORE, ONE MIGHT DETERMINE A MORE ACCURATE INDICATION OF THE BENEFIT VARIATIONS AND THE ACTUAL DEVIATIONS IN THE BENEFIT-COST RATIO.

ESTIMATION VARIATIONS OF THE MAGNITUDE ACTUALLY FOUND IN PRACTICE COULD AFFECT THE JUSTIFICATION OF A PROJECT, IF SUCH VARIATIONS WERE KNOWN TO THE DECISION-MAKERS PRIOR TO PROJECT AUTHORIZATION AND MIGHT RESULT IN A CURTAILED SPENDING

PROGRAM OR A RE-EVALUATION OF PUBLIC WORKS EXPENDITURE POLICIES. HOWEVER, THIS INVESTIGATION DID NOT INTEND TO IMPLY THAT PUBLIC WORKS SPENDING SHOULD NECESSARILY BE CURTAILED, RATHER, THAT THE DECISION-MAKER SHOULD BE PROVIDED WITH A TRUE PICTURE OF POSSIBLE VARIATIONS IN THE ESTIMATED COMPONENTS SO THAT ANY DECISION MIGHT BE MADE WITH AN INCREASED KNOWLEDGE OF WHAT THE POSSIBLE RANGE OF OUTCOMES MIGHT BE. ADEQUATE KNOWLEDGE OF THESE OUTCOMES WOULD BE NECESSARY BEFORE THE AVAILABLE CAPITAL COULD BE RATIONED AMONG THE COMPETING PROJECTS AT A PARTICULAR TIME IN A WAY WHICH WOULD SEEM TO PROVIDE THE GREATEST NATIONAL BENEFIT.

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APPENDIX A. CORRELATION OF ACREAGE UNDER IRRIGATION TO GROSS CROP VALUES

Proposed Method -

The value of the percentage deviation of actual benefits from estimated benefits, R_B', found in the preceding study, represented the deviations of the acreage now under irrigation from the potential acreage to be placed under irrigation when the project achieved full development. This representation assumed that the distribution of the deviations found for the acreage under irrigation would approximate the distribution of the deviations of the total benefits derived from the irrigation investment. Irrigation benefits have been considered to be principally derived from the value of the crops grown on the project; therefore, one might test the validity of the above-mentioned assumption by determining the degree of correlation between the annual acreage under irrigation for a particular project and the annual gross crop value derived from this acreage.[1]

Since the data for the above correlation would be generated over a relatively long span of time, this comparison might be affected by time-related trends. Thus, in order to provide a more comprehensive evaluation of the changes in

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[1]For a detailed discussion of the determination of the direct and indirect benefits to be derived from a project, see Reclamation Manual, Vol. 13 (83).

GROSS CROP VALUES WHICH WOULD RESULT FROM CHANGES IN ACREAGE UNDER IRRIGATION, TRENDS WHICH WOULD BE A FUNCTION OF TIME WOULD BE ELIMINATED FROM THIS ANALYSIS THROUGH THE USE OF A FIRST DIFFERENCE EQUATION. THE SYMBOLS TO BE USED IN THIS FIRST DIFFERENCE EQUATION ARE AS FOLLOWS:

ΔGV = THE DIFFERENCE IN GROSS CROP VALUES BETWEEN TWO CONSECUTIVE YEARS,

ΔP = THE DIFFERENCE IN THE INDICES OF THE PRICES OBTAINED BY THE FARMER FOR SELECTED COMMODITIES BETWEEN TWO CONSECUTIVE YEARS,

ΔA = THE DIFFERENCE IN THE ACRES UNDER IRRIGATION BETWEEN TWO CONSECUTIVE YEARS,

ΔT = A DUMMY VARIABLE INTRODUCED INTO THE EQUATION TO REPRESENT THE DIFFERENCES IN YIELD PER ACRE (TECHNOLOGICAL DIFFERENCES) OR CHANGES IN CROP ROTATION BETWEEN TWO CONSECUTIVE YEARS,

I = THE CODE NUMBER REPRESENTING A PARTICULAR PROJECT OF M PROJECTS,

J = A PARTICULAR YEAR FROM THE N YEARS OF THE PROJECT'S EXISTENCE,

K = THE PARTICULAR COMMODITY OF Q COMMODITIES COMPRISING THE PROJECT'S OR RECLAMATION REGION'S OUTPUT,

S = A CONSTANT INTRODUCED TO ABSORB CHANGES IN ΔT.

THIS FIRST DIFFERENCE EQUATION REPRESENTING THE CHANGE IN GROSS CROP VALUE DUE TO CHANGES IN IRRIGATED ACREAGE COULD BE

WRITTEN IN GENERAL TERMS AS:

$$\Delta GV_{IJ} = F(\Delta P_{IJK}, \Delta A_{IJ}, \Delta T_{IJ}), \quad I = 1, 2, \ldots, M, \quad (33)$$

$$J = 1, 2, \ldots, N,$$

$$K = 1, 2, \ldots, Q,$$

$$\text{WHERE } \Delta P_{IJK} = \sum_{K=1}^{Q} (P_{I,J} - P_{I,J-1})$$

$$\Delta A_{IJ} = A_{I,J} - A_{I,J-1}$$

$$\Delta T_{IJ} = J + S - J.$$

EQUATION 33 COULD BE WRITTEN MORE EXPLICITLY AS:

$$\Delta GV_{IJ} = \sum_{K=1}^{Q} (P_{I,J} - P_{I,J-1}) + \Delta A_{I,J} + \Delta T_{I,J} \quad (34)$$

$$I = 1, 2, \ldots, M,$$

$$J = 1, 2, \ldots, N,$$

$$K = 1, 2, \ldots, Q.$$

THUS, EQUATION 34 WOULD SHOW THE CHANGES IN GROSS CROP VALUES ATTRIBUTAL TO CHANGES IN ACREAGE UNDER IRRIGATION, FOR THE EFFECT OF CHANGES IN COMMODITY PRICES, YIELD PER ACRE, AND CROP ROTATION HAVE BEEN NEUTRALIZED.

WHILE THE CHANGES IN COMMODITY PRICES WOULD BE COMPENSATED FOR IN EQUATION 34, ADDITIONAL DISCUSSION AS TO THE NATURE OF THESE COMMODITY INDICES MIGHT BE PERTINENT AT THIS TIME. SINCE THE CROPS GROWN ON RECLAMATION PROJECTS VARY FROM REGION TO REGION, A NATIONAL INDEX OF PRICES OBTAINED BY THE FARMER COULD LEAD TO POOR RESULTS THROUGH INAPPROPRIATE WEIGHTING FACTORS AND AGGREGATION BIAS. ALSO, IF EACH CROP GROWN WERE INTRODUCED INTO THE EQUATION THROUGH A SEPARATE INDEX, THE

DEGREES OF FREEDOM MIGHT BE REDUCED TO SUCH A LEVEL THAT THE RESULTS OF THE COMPUTATION COULD LACK SIGNIFICANCE.

A COMPROMISE SOLUTION WOULD BE TO ACCEPT THE COMMODITY GROUPINGS USED BY THE BUREAU OF RECLAMATION, WITH MINOR CHANGES, AND TO DEVELOP A SET OF COMMODITY INDICES FOR EACH RECLAMATION REGION. PROJECTS WITHIN A RECLAMATION REGION HAVE A MUCH GREATER HOMOGENEITY OF CROPS PRODUCED THAN IS FOUND BETWEEN PROJECTS OF SEPARATE REGIONS OR BETWEEN THE REGIONS THEMSELVES. THUS, ILLUSTRATION 16, PAGE 150, SHOWS THE COMMODITY GROUPING WHICH MIGHT BE USED IN ESTABLISHING PRICE INDICES, AND THE COMMODITIES WHICH MIGHT BE APPROPRIATELY INCLUDED IN THE CORRELATION OF GROSS CROP VALUES TO ACREAGE UNDER IRRIGATION FOR A PARTICULAR REGION. THE TEST OF WHETHER OR NOT TO CONSIDER A COMMODITY FOR A PARTICULAR REGION WAS WHETHER OR NOT THE COMMODITY PROVIDED AT LEAST FIVE PER CENT OF THE GROSS CROP VALUE OF THAT REGION. HOWEVER, SPECIFIC COMMODITIES DOMINATE TWO OF THE COMMODITY GROUPS. THE CEREALS GROUPING IS DOMINATED BY WHEAT AND BARLEY WHILE THE FORAGE GROUPING IS DOMINATED BY ALFALFA HAY, DOMINATED TO THE EXTENT THAT THESE COMMODITIES CONSTITUTE THE MAJOR PORTION OF THE GROSS CROP VALUE IN THEIR RESPECTIVE GROUPINGS. THUS, PRICE INDICES FOR THESE COMMODITIES COULD CONCEIVABLY BE SUBSTITUTED FOR THE GROUP COMMODITY INDICES WITHOUT INTRODUCING APPRECIABLE BIAS. EQUATION 34 SPECIFICALLY WRITTEN FOR REGION FOUR WOULD THEN BE:

$$\Delta GV4_J = (P_{4J1} - P_{4,J-1,1}) + (P_{4J2} - P_{4,J-1,2})$$

Index Code	Commodity	Region						
		1	2	3	4	5	6	7
1	Cereals	X	X		X		X	X
2	Forage	X	X	X	X	X	X	X
3	Cotton		X	X		X		
4	Sugar Beets	X					X	X
5	Vegetables	X	X	X	X			X
6	Seeds	X		X				
7	Fruits	X	X	X	X			

Illustration 16. Commodity price indices to be included in a regional regression equation

$$+ (P_{4J5} - P_{4,J-1,5}) + (P_{4J7} - P_{4,J-1,7})$$
$$+ (A_{4J} - A_{4,J-1}) + (J + S - J).$$

If one desired to refine the proposed model, the price indices could be weighted according to the relative gross values of the crops grown on the projects in question. The weighted indices would provide an indication as to the degree of effect upon changes in gross crop values provided by the changes in individual commodity indices.

Implication of the Results

Equation 33 would provide information on the annual changes in gross crop values resulting from three sources. First, when the gross crop value varied from one year to the next, but the commodity price indices and acreage under irrigation remained constant, equation 33 implies that the change in the gross crop value would result from an increased crop yield or from the substitution of a crop with a different gross value. Second, when the gross crop value varied while the acreage and the yield factor remained constant, the change in gross value was implied to be the result of variations in the commodity prices. Finally, when the gross crop value changed while the commodity prices and the yield factor remained constant, the change has implied to be the result of a change in the acreage under irrigation. Thus, by neutralizing commodity price effects and effects of yields and crop rotation, as was done in equation 33, one may test the hypothesis that gross crop values derived from a

RECLAMATION INVESTMENT, AND, THUS, THE IRRIGATION BENEFITS ARE DIRECTLY PROPORTIONAL TO THE NUMBER OF ACRES UNDER IRRIGATION.

APPENDIX B. DEMONSTRATION OF THE USE OF THE CONTINGENCY INDEX TECHNIQUE

CALCULATION OF THE CONTINGENCY INDICES FOR THE BOISE PROJECT

ESTIMATED BENEFITS - B_E

$$B_E = \Sigma(\text{ESTIMATED ACRES TO BE IRRIGATED})$$

$$B_E = 372{,}000 \text{ ACRES}$$

ACTUAL BENEFITS - B_A

$$B_A = \frac{1}{10}(A_N - 10 + \cdots + A_N)$$

WHERE A_N = ACRES UNDER IRRIGATION IN YEAR N

$$= \frac{1}{10}(321{,}484 + \cdots + 322{,}380)$$

$$B_A = 324{,}991 \text{ ACRES}$$

BENEFIT CONTINGENCY INDEX - ρ_B

$$\rho_B = \text{LN}\left[\frac{B_A}{B_E}\right]$$

$$= \text{LN}\left[\frac{324{,}991}{372{,}000}\right]$$

$$\rho_B = -0.1351$$

ESTIMATED COSTS - C_E

$$C_E = \sum\left[\text{ESTIMATED CONSTRUCTION COSTS AT AUTHORIZATION}\right]\left[\frac{1}{(1+i)^T}\right]\left[\frac{100}{ENR_N}\right]$$

WHERE ENR_N = ENGINEERING NEWS-RECORD CONSTRUCTION COST INDEX FOR YEAR N

$$= (11{,}000{,}000)\left[\frac{1}{(1+0.025)^0}\right]\left[\frac{100}{95.10}\right] + \cdots$$

$$+ (13{,}100{,}000)\left[\frac{1}{(1+0.025)^{34}}\right]\left[\frac{100}{241.96}\right]$$

$$C_E = \$22{,}020{,}500$$

ACTUAL COSTS - C_A

$$C_A = \sum \left[\text{ANNUAL CONSTRUCTION COST}\right] \left[\frac{1}{(1+i)^T}\right] \left[\frac{100}{ENR_N}\right]$$

$$= (12,117,525) \left[\frac{1}{(1+0.025)^0}\right] \left[\frac{100}{95.10}\right] + \cdots$$

$$+ (-223,568) \left[\frac{1}{(1+0.025)^{57}}\right] \left[\frac{100}{900.73}\right]$$

$$C_A = \$18,945,600$$

COST CONTINGENCY INDEX - ρ_C

$$\rho_C = LN\left[\frac{C_E}{C_A}\right]$$

$$= LN\left[\frac{22,020,500}{18,945,600}\right]$$

$$\rho_C = 0.1504$$

CONTINGENCY INDEX - ρ_{BC}

$$\rho_{BC} = \rho_B + \rho_C$$

$$= -0.1351 + 0.1504$$

$$\rho_{BC} = 0.0153$$

CALCULATION OF THE OBSERVED CONTINGENCY INDICES AND ACCURACY INDICES FOR THE SAMPLE

OBSERVED BENEFIT CONTINGENCY INDEX - I_B

$$I_B = E[\rho_B]$$

$$= \frac{1}{N}\left[\rho_{B_1} + \cdots + \rho_{B_N}\right]$$

$$= \frac{1}{48}\left[(-0.6752) + \cdots + (-0.1065)\right]$$

$$I_B = -0.30254$$

OBSERVED COST CONTINGENCY INDEX - I_C

$$I_C = E[\rho_C]$$

$$= \frac{1}{N}\left[\rho_{C_1} + \cdots + \rho_{C_N}\right]$$

$$= \frac{1}{48}\left[(0.2846) + \cdots + (-0.2194)\right]$$

$$I_C = -0.28082$$

OBSERVED CONTINGENCY INDEX - I_{BC}

$$I_{BC} = I_B + I_C$$

$$= (-0.30254) + (-0.28082)$$

$$I_{BC} = -0.58336$$

BENEFIT ACCURACY INDEX - J_B

$$J_B = E\left[\rho_B{}^2\right] - (E\left[\rho_B\right])^2$$

$$= \frac{1}{N}\left[\rho_{B_1}{}^2 + \cdots + \rho_{B_N}{}^2\right] - (I_B)^2$$

$$= \frac{1}{48}\left[(-0.6752)^2 + \cdots + (-0.1065)^2\right] - (-0.30254)^2$$

$$J_B = 0.23842$$

COST ACCURACY INDEX - J_C

$$J_C = E\left[\rho_C{}^2\right] - (E\left[\rho_C\right])^2$$

$$= \frac{1}{N}\left[\rho_{C_1}{}^2 + \cdots + \rho_{C_N}{}^2\right] - (I_C)^2$$

$$= \frac{1}{48}\left[(0.2846)^2 + \cdots + (-0.2194)^2\right] - (-0.28082)^2$$

$$J_C = 0.28824$$

ACCURACY INDEX - J_{BC}

$$J_{BC} = J_B + J_C + 2\rho\sqrt{(J_B)(J_C)}$$

$$= 0.23842 + 0.28824$$

$$+ 2(-0.19110)\sqrt{(0.23842)(0.28824)}$$

$$J_{BC} = 0.42646$$

Demonstration of the Use of the Contingency Index to Adjust Future Estimates

Expected Value Adjustment - Yellow Tail Project

$$\ln(Z_A) = \ln(Z) + I_{BC}$$

where Z = estimated benefit-cost ratio

Z_A = adjusted benefit-cost ratio

$$= \ln(1.50) + (-0.58336)$$

$$Z_A = 0.84$$

95% Confidence Interval - CI

$$\ln(CI) = \ln(Z_A) \pm 2\sqrt{J_{BC}}$$

$$= \ln(0.84) \pm 2\sqrt{0.42646}$$

$$CI = 3.1 \text{ to } 0.22$$

APPENDIX C. DEMONSTRATION OF THE MULTIVALUED ESTIMATION TECHNIQUE

If historical data were not available or appropriate, an approximate distribution of possible outcomes of an estimated benefit-cost ratio could be obtained through the use of multivalued estimates. A demonstration of this technique as applied to the proposed Middle Rio Grande Reclamation Project has been provided in this appendix.

The first step in the procedure was to choose arbitrarily a type of distribution which might be applicable to the possible outcomes associated with estimates of benefits and costs. A beta distribution was selected for this analysis, and while the selection was arbitrary, MacCrimmon and Ryavec (41, p. 22) have pointed out that when the mode of the distribution is reasonably centralized, as was the case in the sample of reclamation projects analyzed in this investigation, the error in the expected value resulting from an incorrect choice of a distribution would be approximately eleven per cent. An error of this magnitude would seem to be smaller than the error shown by this investigation to result from ignoring the distribution of possible outcomes. Likewise, the worst absolute error in the standard deviation would be approximately seventeen per cent, regardless of the modal characteristics (41, p. 22). Thus, the calculations which follow would provide a demonstration of a method of

RECOGNIZING THE RANGE OF POSSIBLE OUTCOMES ASSOCIATED WITH A BENEFIT-COST ESTIMATE WHILE INTRODUCING A MINIMUM AMOUNT OF ERROR.

SINCE THE ESTIMATES OF BENEFITS AND COSTS, AS SHOWN IN TABLE 12, PAGE 159, WERE ASSUMED TO BE INDEPENDENT, THE EXPECTED VALUE AND THE VARIANCE OF THE TOTAL COSTS AND BENEFITS WOULD BE THE RESPECTIVE SUM OF THE EXPECTED VALUES AND VARIANCES OF THE INDIVIDUAL FACTORS. THEREFORE FROM EQUATION 31, PAGE 124,

$$E\left[B_{ID}\right] = \frac{\$3,523,000 + 4(\$2,791,000) + (\$1,980,000)}{6},$$

$$E\left[B_{ID}\right] = \$2,778,000,$$

WHERE $E\left[B_{ID}\right]$ = THE EXPECTED VALUE OF THE DIRECT BENEFITS OF IRRIGATION AND DRAINAGE,

AND FROM EQUATION 32, PAGE 125,

$$\sigma_{ID} = \frac{\$3,523,000 + \$1,980,000}{6},$$

$$\sigma_{ID} = \$917,000,$$

WHERE σ_{ID} = THE STANDARD DEVIATION ASSOCIATED WITH THE ESTIMATE OF DIRECT BENEFITS OF IRRIGATION AND DRAINAGE.

THE VARIANCE OF THE DIRECT BENEFITS OF IRRIGATION AND DRAINAGE, σ_{ID}^2, WOULD THEN BE

$$\sigma_{ID}^2 = (\$917,000)^2,$$

$$\sigma_{ID}^2 = 840,889,000.$$

THE BENEFIT-COST RATIO, Z, OF THE PROJECT WOULD BE FOUND USING THE EXPECTED VALUES OF COSTS AND BENEFITS FOR THE

TABLE 12. APPLICATION OF THE MULTIVALUED ESTIMATION TECHNIQUE TO DATA APPROXIMATING THAT FOUND FOR THE MIDDLE RIO GRANDE PROJECT[A]

ITEM	MOST FAVORABLE ESTIMATE[B]	MOST LIKELY ESTIMATE[C]	LEAST FAVORABLE ESTIMATE[B]	EXPECTED VALUE[D] $ THOUSAND	STANDARD DEVIATION $ THOUSAND[E]	VARIANCE[F] $ THOUSAND
ANNUAL BENEFITS						
DIRECT BENEFITS						
IRRIGATION & DRAINAGE	3,523	2,791	1,980	2,778	917	840,889
SEDIMENTATION CONTROL	4,130	3,492	1,845	3,324	996	992,016
INUNDATION & SCOUR	500	470	325	451	138	19,044
RECREATION	170	56	10	67	30	900
FISH & WILDLIFE	0	- 62	- 120	- 61	20	400
TOTAL				6,559[G]		1,853,249[G]
INDIRECT BENEFITS						
IRRIGATION & DRAINAGE	3,175	2,576	1,657	2,523	805	648,025
SEDIMENTATION CONTROL	3,820	2,839	1,230	2,734	841	707,281
INUNDATION & SCOUR	250	219	100	204	58	3,364
RECREATION	150	1	0	26	25	625
TOTAL				5,487		1,359,295
TOTAL BENEFITS				12,046		3,212,544
ANNUAL COSTS						
CONSTRUCTION COSTS						
DAMS & RESERVOIRS	1,620	2,307	4,730	2,596	1,058	1,119,364
LEVEE IMPROVEMENTS	25	32	95	41	20	400
CHANNEL RECTIFICATION	210	330	710	373	153	23,409
IRRIGATION & DRAINAGE	515	642	1,525	768	340	115,600
OTHER	38	54	85	56	20	400
TOTAL				3,834		1,259,173
OPERATION & MAINTENANCE						
DAMS & RESERVOIRS	110	138	315	163	71	5,041
CHANNEL RECTIFICATION	395	421	970	508	228	51,984
IRRIGATION & DRAINAGE	450	499	1,115	594	261	68,121
OTHER	50	56	127	67	30	900
TOTAL				1,332		126,046
TOTAL COSTS				5,166		1,385,219

[A]SOURCE: 105, PP. 165, 167.

[B]THE VALUES PROVIDED HAVE BEEN ESTIMATED FOR ILLUSTRATIVE PURPOSES. THE WRITER HAS NOT HAD SUFFICIENT EXPERIENCE WITH THE MIDDLE RIO GRANDE PROJECT TO ESTABLISH A VALID RANGE OF EXTREME VALUES.

[C]THESE VALUES WERE PROVIDED BY THE AUTHORIZATION DOCUMENT AND WERE ASSUMED TO REPRESENT ESTIMATES OF THE MOST LIKELY DETERMINATION OF BENEFITS AND COSTS.

[D]THESE VALUES WERE FOUND BY EQUATION 31.

[E]THESE VALUES WERE FOUND BY EQUATION 32.

[F]THESE VALUES WERE FOUND BY SQUARING THE VALUES OF THE STANDARD DEVIATION.

[G]THE ESTIMATES OF COSTS AND BENEFITS WERE ASSUMED TO BE INDEPENDENT; THEREFORE, THE EXPECTED VALUES AND VARIANCES WERE ADDITIVE.

ASSUMED DISTRIBUTION.

$$Z = \frac{\text{TOTAL BENEFITS}}{\text{TOTAL COSTS}},$$

$$Z = \frac{\$12,046,000}{5,166,000},$$

$$Z = 2.33.$$

THE VARIANCE OF THE BENEFIT-COST RATIO COULD BE FOUND THROUGH THE RELATIONSHIP FOR THE APPROXIMATION OF THE VARIANCE OF A RATIO BASED ON A TAYLOR SERIES. THIS APPROXIMATE VARIANCE, σ_Z^2, WOULD BE WRITTEN AS:

$$\sigma_Z^2 \doteq \left[\frac{\partial Z}{\partial B}\right]^2 \sigma_B^2 + \left[\frac{\partial Z}{\partial C}\right]^2 \sigma_C^2 + 2\left[\frac{\partial Z}{\partial B}\right]\left[\frac{\partial Z}{\partial C}\right] \sigma_{BC}.$$

HOWEVER, SINCE THE BENEFIT AND COST ESTIMATES ARE ASSUMED TO BE INDEPENDENT, THE LAST TERM OF THE EXPRESSION WOULD EQUAL ZERO AND THE ABOVE EXPRESSION COULD BE REWRITTEN AS:

$$\sigma_Z^2 \doteq \left[\frac{\partial Z}{\partial B}\right]^2 \sigma_B^2 + \left[\frac{\partial Z}{\partial C}\right]^2 \sigma_C^2.$$

SINCE $Z = \frac{B}{C}$,

THEN $\frac{\partial Z}{\partial B} = \frac{1}{C}$

AND $\frac{\partial Z}{\partial C} = -\frac{B}{C^2}$;

THEREFORE, $\sigma_Z^2 \doteq \left[\frac{1}{C}\right]^2 \sigma_B^2 + \left[\frac{-B}{C^2}\right]^2 \sigma_C^2.$

SUBSTITUTING THE VALUES OF THE VARIABLES FOUND IN TABLE 12, PAGE 159, IN THE ABOVE EXPRESSION,

$$\sigma_Z^2 \doteq \left[\frac{1}{5166}\right]^2 (3,212,544) + \left[\frac{12,046}{(5166)^2}\right]^2 (1,385,219),$$

$$\sigma_z^2 \doteq 0.403.$$

FINALLY, AN APPROXIMATE NINETY-FIVE PER CENT CONFIDENCE INTERVAL, CI, MIGHT BE ESTABLISHED BY FINDING A REGION OF TWO STANDARD DEVIATIONS ON EITHER SIDE OF THE EXPECTED VALUE.

$$CI = Z \pm 2\sqrt{\sigma_z^2},$$

$$= 2.33 \pm 2\sqrt{0.403},$$

$$CI = 1.06 \text{ TO } 3.60.$$