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MEASUREMENT AND EVALUATION OF ALTERNATIVE REGIONAL TRANSPORTATION MIXES: VOLUME III, EXAMPLE

Frederick S. Pardee, Charles T. Phillips and Keith V. Smith

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PREFACE

This memorandum is the third of three volumes [1] summarizing the second phase of The Rand Corporation's research for the Transport Systems Planning Division, Office of High Speed Ground Transportation, U.S. Department of Transportation. These, in turn, are part of a larger series [2-10] whose overall objective is development of a comprehensive and systematic methodology for evaluating alternative transportation proposals. Emphasis in this second phase is on evaluation of alternative mixes of transportation modes, operating over a network of links and nodes, and embedded in a regional environment.

This third volume is a companion piece to Vol. II [1]. It illustrates the application of the methodology developed during both phases of the research with particular attention to comprehensive comparison and evaluation of alternative investments in transportation service for a given region.

For further discussion on the purpose, context, and possible uses of the study, the reader is referred to the Preface of Vol. II [1] where the methodology is described more fully.

KHI-6234 Vol I

SUMMARY

The objective of this volume is to illustrate the application of a detailed methodology for evaluating alternative proposed changes to an existing mix of transportation modes. The setting for the example is a geographical region that is part of the Northeast Corridor of the United States. Two alternative environments and three alternative transportation mixes are specified for the region over the 1970 to 2000 time period. Populations in the region's cities and distributions within these cities are assumed for each environment.

Two separate evaluations are performed to determine region-wide user benefits. The first is performed without extensive computer assistance. It determines worth information in an aggregated manner for the transportation network as a whole. The second is a computer-oriented method that determines worth information for each possible trip in a network, using a shortest path algorithm to specify the trip--including access, egress, and transfer links. Both evaluations produce a variety of summary information and, if desired, will generate a single measure of worth combining a large number of user attributes.

Two comprehensive evaluations are also performed to determine societal benefits. In the more extensive of these, the region is partitioned so that effects can be measured that are related to the transportation links, to the cities in the network, and to the rural areas of the region. In each specified area, a worth estimate is made for each attribute, and the number of residents affected by each attribute is estimated. A computer performs the accounting necessary to produce various summaries of aggregate worth.

In addition to the comprehensive societal evaluation, more detailed analyses of selected individual societal attributes are presented. An evaluation of air pollution is made to show the details of spatial structuring. Several of the range of methods described in Vol. II [1] are compared briefly through application to the noise attribute. A qualitative analysis is suggested for the housing attribute to measure its dimensions and show how it is indirectly influenced by transportation changes.

In a concluding section, user, operator, and societal evaluations are aggregated. Various sensitivity analyses are performed on the incremental benefits obtained by implementing transportation proposals. Benefit and cost information are matched, and the relation between the effectiveness of transportation proposals and desired policy options are explored and illustrated.

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The report has benefited significantly from the careful reviews provided by S. H. Dole and D. C. Gogerty, and from suggestions during the research by G. H. Fisher, W. Z. Hirsch, and David Novick.

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GLOSSARY OF SYMBOLS

$1 \leq n \leq N$ Nodes

$1 \leq m \leq M$ Modes

$1 \leq \ell \leq L$ Links

$1 \leq z \leq Z$ Zones

$1 \leq r \leq R$ Regional environment

$1 \leq g \leq G$ Groups

$1 \leq t \leq T$ Time periods

$1 \leq a \leq A$ Attributes

$1 \leq j \leq J$ System improvement

i = Travel origin

k = Travel destination

H = Physical attribute measure

U = User worth

V = Societal worth

E = Societal worth for an attribute

P = Population

D = Travel demand

Q = Travel incidence

W = Attribute weight

X = Travel routing

F = Weighted worth

B = System benefit

C = System cost

I = Link flow

K = Calibration constant

θ = Policy weight

α = User and societal weights

ψ = Benefit cost ratio

π = Probability

A bar over a symbol indicates a matrix or vector. Subscripts, superscripts, and arguments in parentheses for a particular symbol are used to explain its precise context in the discussion. The superscript 0 refers to the base case transportation mix.

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I. INTRODUCTION

This volume provides a detailed discussion of the examples that have been generated during the second phase of our project to develop transportation evaluation methodology. These examples illustrate the methods described in Vol. II [1] of this series. As a result, the volume is organized in a manner similar to the flowchart of steps in the methodology, which appears in Vol. II [1] and is repeated here as Fig. 1.

The region chosen as the setting for the examples is a portion of the Northeast Corridor. In Sec. II, two different sets of assumptions on population growth in the region are postulated to define two alternative regional environments reflected in the transportation analysis. Associated with these patterns of population growth is a model showing the distribution by residential and employment location in each city in the region, both geographically and by income group. The transportation modes in a base case as well as two alternative mixes of modes are identified, and the performance characteristics of each are measured. The availability or time phasing of each transportation improvement within the total planning horizon is indicated.

Section III presents an abbreviated technique for analyzing user benefits for each mix of modes in each regional environment. The technique involves calculating both user demand and estimated worth on the basis of passenger miles. The calculations are primarily manual, and the summary results are suggested as an approximation of those that would be produced using the more comprehensive methodology suggested in the next section. The procedure does not involve calculations for specific links or origin-destination pairs, but instead focuses on major sections of the overall network or region.

Section IV explores the steps in a more detailed, network-oriented analysis of user benefits. Evolution of the methodology is described in terms of a series of successive computer routines incorporating increasing numbers of the variables relevant in evaluating transportation alternatives. The first routine starts simply and is of a single user attribute and a single travel mode. The second analysis is of a single user attribute and a mix of transportation modes. The third analysis

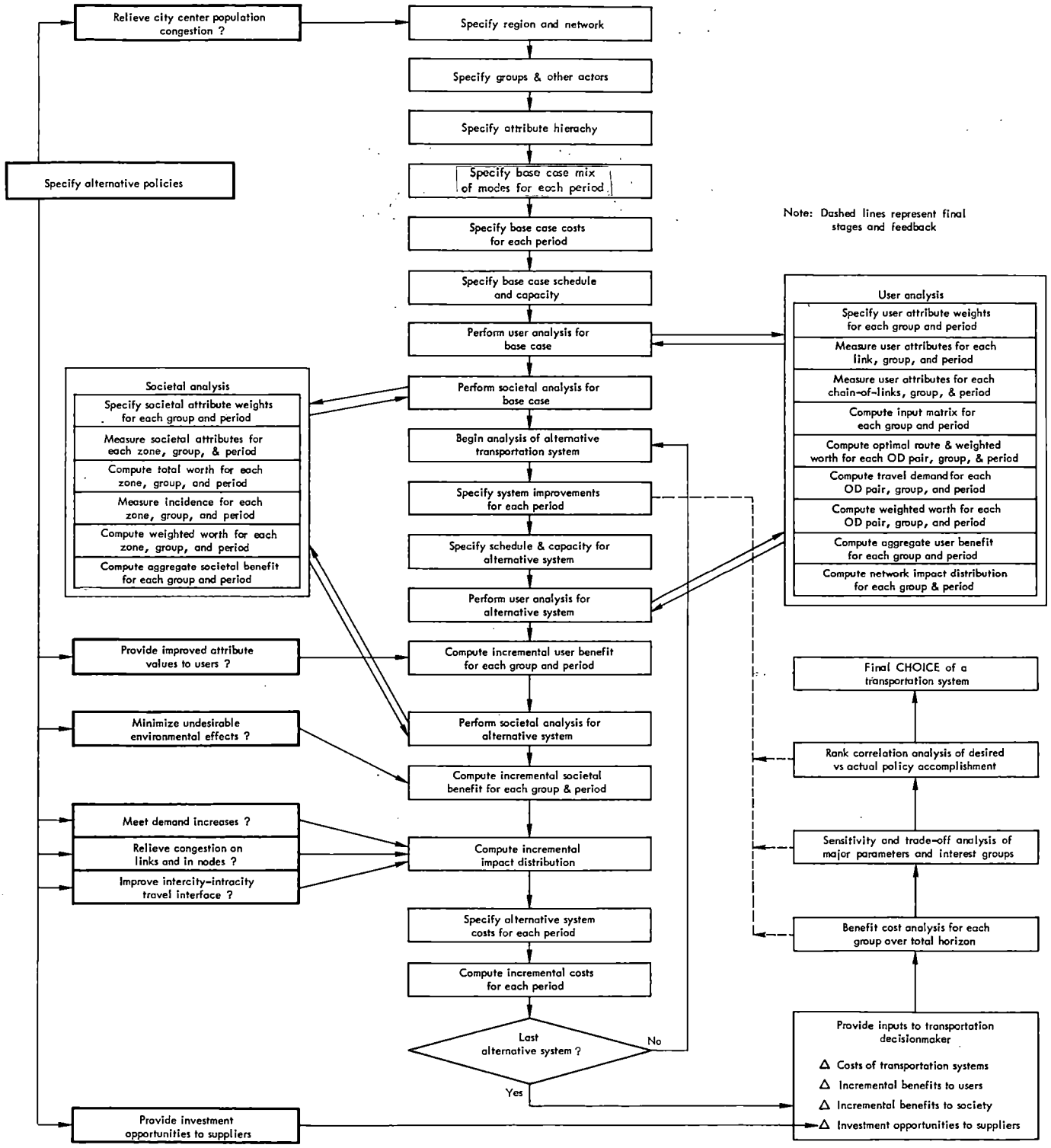


Fig. 1--Flow chart analysis of transportation system effectiveness mix-of-modes/network methodology

includes the entire hierarchy of user attributes, as well as the entire mix of transportation services. For the latter analysis, a careful description is made of link-associated attributes, chain-of-link attributes, and the access-egress portions of total trips. These variables are carefully quantified so that a shortest-path algorithm can be used to determine the optimal routing over links and nodes for each origin-destination pair. Results of that algorithm are used to estimate the demand for all possible trips. Demand and worth information are then combined into aggregate measures of user benefit for each user group and time period.

Section V illustrates more detailed analyses of individual societal effects. Evaluations of air pollution and noise are used to illustrate how each societal attribute can be measured and assessed in a complete analysis. Also included is a detailed listing of possible qualitative and quantitative measures for the housing attribute, with preliminary attention given to tracing indirect or second-order influences of transportation on housing.

This is followed in Sec. VI by two analyses of societal benefits for the entire network. First, an overall direct worth evaluation is illustrated. Then the total network is partitioned geographically so that a location-specific analysis of societal benefits, paralleling the user benefit analysis of Sec. IV, can be made. Societal attribute worths are estimated for different nodes (cities) and links of the network and appropriate aggregations are made. The number of people affected is also calculated so that overall societal worths can be estimated accordingly.

Results of the societal analysis can then be combined with those of the user analysis into a total evaluation of transportation alternatives within a network and under various assumptions about the regional environment. Section VII illustrates how the detailed information of the user and societal studies can be brought together in such a total analysis. Sensitivity analyses that the transportation planner may perform, using such information, are described.

Sections II, III, VI, and VII, in combination, present a complete example resulting in aggregate measures that can be used to compare

the alternative mixes of transportation modes. Section IV is included to illustrate methodology, which is still exploratory, for more realistically incorporating the network dimension into the analysis, while Sec. V illustrates the possible application of alternative measurement methods to the obviously very difficult problem of properly capturing societal inputs. It particularly emphasizes quantification of impacts in physical, as contrasted with worth, units. Cross-references to Vol. II [1] for further discussion of the methodology being illustrated throughout this volume are provided at the beginning of each section.

II. REGIONAL ENVIRONMENTS, POPULATION DISTRIBUTIONS, AND TRANSPORTATION ALTERNATIVES*

THE TWO REGIONAL ENVIRONMENTS

As a setting for our examples, we have chosen a portion of the Northeast Corridor between New York and Washington. Figure 2 shows the boundaries of the region and the twenty-four cities assumed to form the nodes in our transportation network. Eighteen of these cities exist today; the other six are hypothetical new cities to be introduced in one of our alternative regional environments.

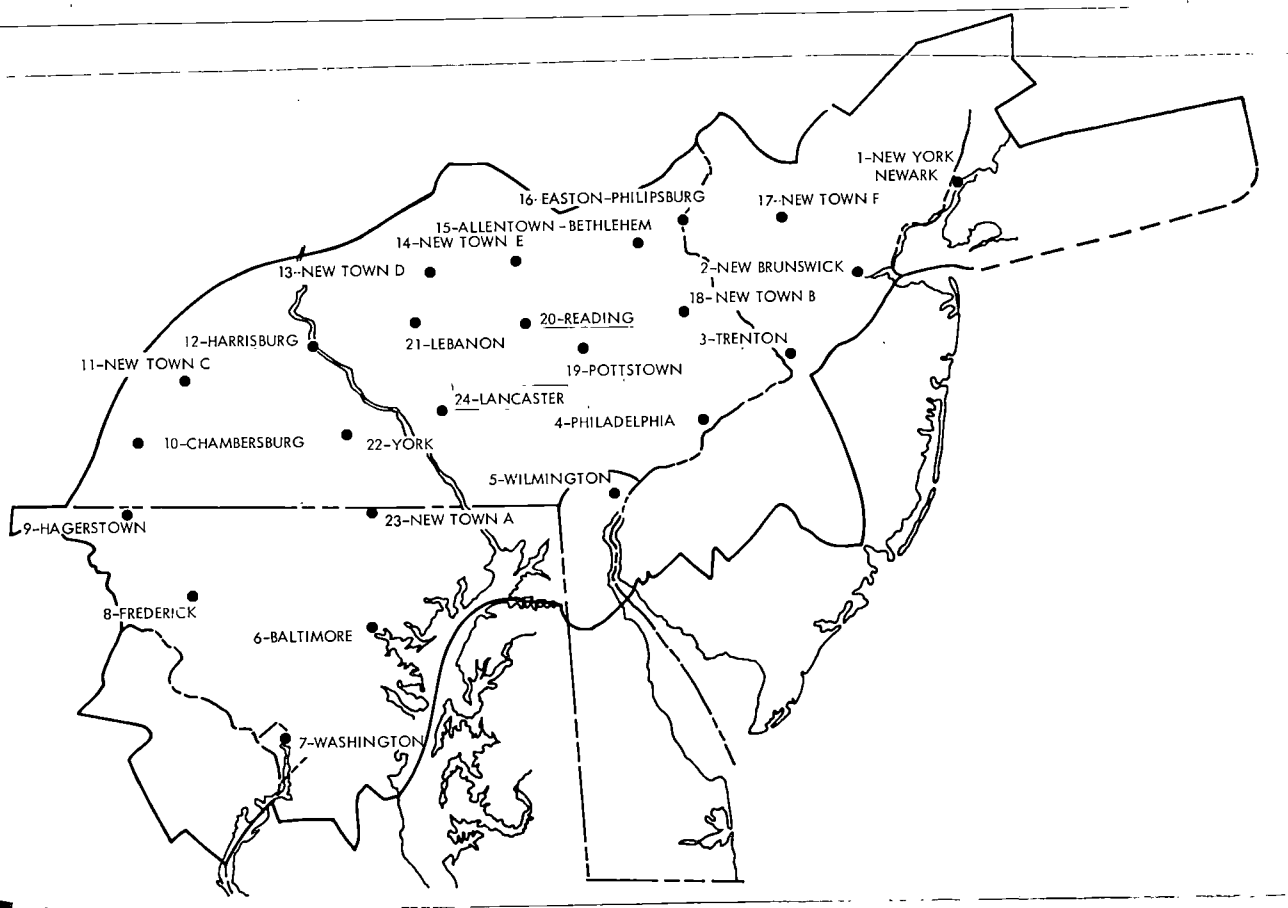


Fig. 2--Cities in the network

*Methodological implications of the material in this section are found in Sec. II of Vol. II [1].

Two sets of population projections have been produced for these cities extending over the time period 1970-2000. The first set is an extrapolation of current trends, which assumes that neither the transportation system itself nor external technological or social events radically influence movements of the population. The second projection is the result of a planned development of the western portion of the region, where transportation changes and other governmental actions are used to shift population away from the crowded cities in the East and into the western portion of the region.

The basic data for both sets of population projections are shown in Table 1. Each metropolitan area has an assumed growth rate per year. Unless otherwise indicated by footnote, the growth rates are derived by comparing Bureau of the Census population estimates for Standard Metropolitan Statistical Areas (SMSAs) on July 1, 1965 with the Census figures on April 1, 1960. Applying these rates to the SMSA or area populations in 1960, we get the estimated 1970 populations. Future new cities, of course, are omitted from this table.

Table 2 shows the 1970-2000 forecasts assuming the extrapolation of current trends--this is referred to as Regional Environment A. Starting with the 1970 base, each city is projected at a standard growth rate. The cities of the central portion of the region (cities 1-7) are assumed to continue to grow at a rate of 1.5 percent per year (similar to the current rate for New York, Philadelphia, and Baltimore), with Washington as an exception with a significantly higher rate because of its unique role as the center of government. The Washington rate, although assumed to be 2.5 percent, is down somewhat from its 1960-1970 rate on the assumption that growth of the Federal Government will slow down. All western portion cities are assumed to grow at a rate of 1.0 percent, which is typical of the 1960-1970 time period. We have also assumed a population in 1970 of one million in the rural areas, growing at 1 percent per year.

Table 2 also shows the 1970-2000 forecast assuming planned development of the Western Region. This we refer to as Regional Environment B. The scenario for Regional Environment B is as follows: In 1970-80, tax incentives and governmental investments in the western

Table 1

POPULATION TREND PROJECTIONS TO 1970

Node No.	City or Area	SMSA or Area Pop. 1960 (millions)	1960-1970 Growth Rate Assumed per Year (%)	1970 SMSA or Area Pop. (est.) (millions)
1	New York-Northeastern New Jersey[a]	14.182	1.3	16.137
2	New Brunswick	.180[b]	2.1[c]	.222
3	Trenton	.266	2.1	.327
4	Philadelphia	4.214[d]	1.4	4.843
5	Wilmington	.415	2.3	.521
6	Baltimore	1.804	1.4	2.073
7	Washington	2.064	3.7	2.968
8	Frederick	.072[e]	1.0[f]	.080
9	Hagerstown	.091[e]	1.0[f]	.101
10	Chambersburg	.088[e]	1.0[f]	.097
12	Harrisburg	.372	1.0	.411
15	Allentown/Bethlehem	.329[g]	0.9	.360
16	Easton/Philipsburg	.163[g]	0.9	.178
19	Pottstown	.129[h]	1.0[f]	.142
20	Reading	.275	0.6	.292
21	Lebanon	.091[e]	1.0	.101
22	York	.290	1.1	.324
24	Lancaster	.278	0.7	.298
Central portion cities (1-7)		23.125	--	27.091
Western portion cities (8-24)		2.177	--	2.384

[a] Contains the New York, Newark, Jersey City, and Paterson-Clifton, Passaic SMSAs.

[b] Allocated 1/2 of Somerset County and 1/4 of Middlesex County population.

[c] Assumed the New Brunswick growth rate is the same as Trenton's.

[d] Subtracted 1/4 of Montgomery County population from the Philadelphia SMSA; this population is allocated to Pottstown.

[e] Population of county containing the city in question.

[f] Assumed 1 percent growth rate for small cities of the Western Region.

[g] Allentown-Bethlehem: Allocated Lehigh County and 1/2 of Northampton County population. Easton-Philipsburg: Allocated Warren County and 1/2 of Northampton County population.

[h] Allocated 1/4 of Montgomery County population.

Table 2

POPULATION PROJECTIONS, 1970–2000

Node No.		Regional Environment A: Assumed Yearly Growth 1970-2000 (%)	Regional Environment A: SMSA or Area Population (millions) 1970[a]	1975	1980	1985	1990	1995	2000	Regional Environment B: Assumed Yearly Growth 1970-1980 (%)	Assumed Yearly Growth 1980-2000 (%)	SMSA or Area Population (millions) 1970[a]	1975	1980	1985	1990	1995	2000
1	New York Area	1.5	16.14	17.39	18.73	20.18	21.74	23.42	25.23	1	-0.5	16.14	16.96	17.83	17.39	16.96	16.54	16.14
2	New Brunswick	1.5	.22	.24	.26	.28	.30	.32	.34	1	-0.5	.22	.23	.24	.23	.23	.22	.22
3	Trenton	1.5	.33	.35	.38	.41	.44	.47	.52	1	-0.5	.33	.34	.36	.35	.34	.33	.33
4	Philadelphia	1.5	4.84	5.21	5.62	6.05	6.52	7.02	7.57	1	-0.5	4.48	4.71	5.35	5.22	5.09	4.96	4.84
5	Wilmington	1.5	.52	.56	.60	.65	.70	.75	.81	1	-0.5	.52	.54	.57	.56	.54	.53	.52
6	Baltimore	1.5	2.07	2.23	2.40	2.59	2.79	3.01	3.24	1	-0.5	2.07	2.18	2.29	2.23	2.18	2.12	2.07
7	Washington	2.5	2.97	3.27	3.80	4.30	4.87	5.51	6.23	2	+0.5	2.97	3.28	3.62	3.71	3.81	3.91	4.00
8	Frederick	1.0	.08	.08	.09	.09	.10	.10	.11	6	10	.08	.11	.14	.23	.37	.60	.96
9	Hagerstown	1.0	.10	.10	.11	.11	.12	.12	.13	6	10	.10	.13	.18	.29	.46	.75	1.20
10	Chambersburg	1.0	.10	.10	.11	.11	.12	.12	.13	6	10	.10	.13	.18	.29	.46	.75	1.20
11	New Town C	---	---	---	---	---	---	---	---	---	20	---	---	---	.02	.05	.12	.31
12	Harrisburg	1.0	.41	.43	.45	.47	.50	.52	.55	4	8	.41	.50	.61	.90	1.32	1.94	2.84
13	New Town D	---	---	---	---	---	---	---	---	---	20	---	---	---	.02	.05	.12	.31
14	New Town E	---	---	---	---	---	---	---	---	---	20	---	---	---	.02	.05	.12	.31
15	Allentown/Bethlehem	1.0	.36	.38	.40	.42	.44	.46	.49	4	8	.36	.44	.53	.78	1.14	1.68	2.47
16	Easton/Philipsburg	1.0	.18	.19	.20	.21	.22	.23	.24	6	10	.18	.24	.32	.52	.83	1.34	2.15
17	New Town F	---	---	---	---	---	---	---	---	---	20	---	---	---	.02	.05	.12	.31
18	New Town B	---	---	---	---	---	---	---	---	---	20	---	---	.02	.05	.12	.31	.77
19	Pottstown	1.0	.14	.15	.15	.16	.17	.18	.19	6	10	.14	.19	.25	.40	.65	1.04	1.68
20	Reading	1.0	.29	.30	.32	.33	.35	.37	.39	4	8	.29	.35	.43	.63	.93	1.36	2.00
21	Lebanon	1.0	.10	.10	.11	.11	.12	.12	.13	6	10	.10	.13	.18	.29	.46	.75	1.20
22	York	1.0	.32	.33	.35	.37	.39	.41	.43	4	8	.32	.39	.47	.69	1.01	1.49	2.19
23	New Town A	---	---	---	---	---	---	---	---	---	20	---	---	.02	.05	.12	.31	.77
24	Lancaster	1.0	.30	.31	.33	.35	.37	.38	.40	4	8	.30	.36	.44	.65	.95	1.40	2.05
Central Portion Cities (1-7)			27.09	29.25	31.65	34.46	37.18	40.50	43.71			27.09	28.24	30.69	29.69	29.15	28.61	28.01
Western Portion Cities (8-24)			2.38	2.47	2.62	2.73	2.90	3.01	3.19			2.38	2.97	3.77	5.85	9.02	14.20	22.72
Rural Areas		1.0	1.00	1.05	1.11	1.17	1.22	1.28	1.35	2	2	1.00	1.10	1.22	1.35	1.49	1.64	1.81
Total			30.47	32.77	35.38	38.36	41.30	44.79	48.25			30.47	32.31	35.25	36.89	39.66	44.45	52.54

[a]Estimated.

portion of the region produce a rapid increase in population there, and a slowing of the increases in the larger cities of the East. The larger western cities grow at 4 percent per year, and the smaller ones at 6 percent. The eastern cities slow to one percent, with the exception of Washington, whose unique role keeps it at a 2 percent growth rate.

In 1980, New Towns A and B are established with populations of 20,000, on routes to be served by new ground modes within five years. Due to massive investment and subsidy, the New Towns grow at a rate of 20 percent per year from their inception to the year 2000. Similarly in 1985, New Towns C, D, E, and F are established on routes to be served by new ground modes within five years.

From 1980 to 2000, the rates of growth in the Western cities are further accelerated, as the development plan goes into high gear. The larger cities now grow at a rate of 8 percent, and the smaller cities at a rate of 10 percent per year. Due to the new attractiveness of the western portion, the eastern cities experience a small out-migration of -0.5 percent per year, with the exception of Washington which continues to grow at +0.5 percent.

We assume as before a rural population of 1 million in 1970, which in this case grows at a rate of 2 percent per year as an induced result of the growth of western cities.

Figure 3 presents a pictorial representation of the current population distribution in 1970 and for each of the two future regional environments in 2000.

POPULATION DISTRIBUTIONS WITHIN THE CITIES

A classification by size has been made of the metropolitan areas (cities) in the region, based on their populations. A city may change its size class over time as it changes in population. For each city type there is a postulated spatial distribution, by income group, of residences and places of employment. The model is designed for the measurement of both user access characteristics and societal impacts.

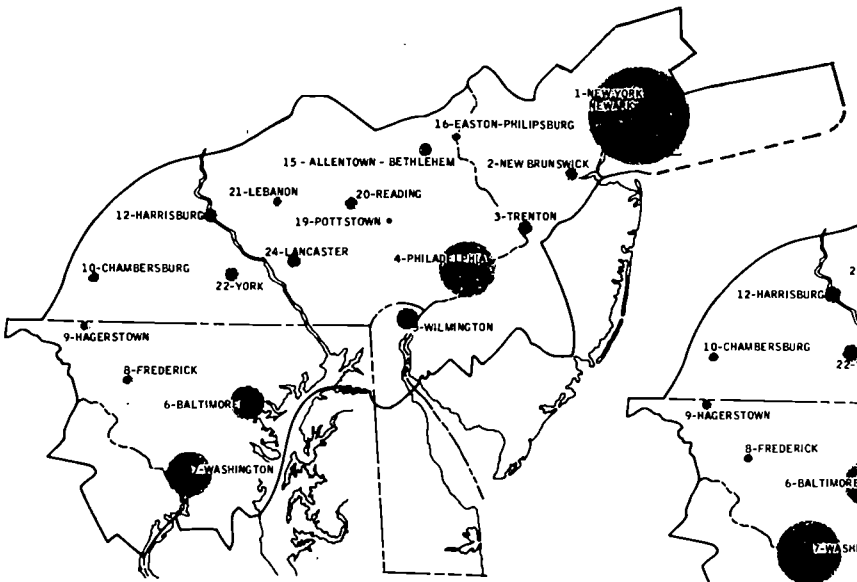


Fig. 3A--Population distribution in 1970

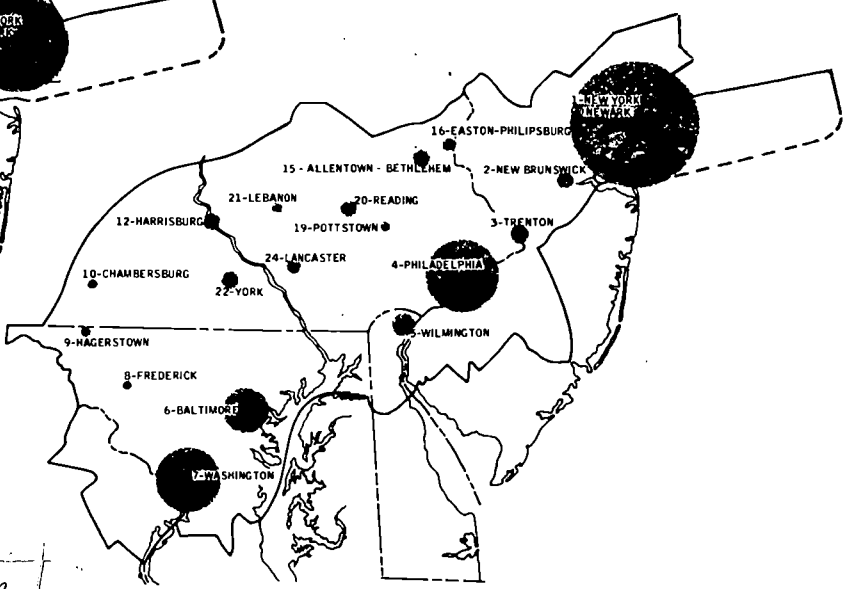


Fig. 3B--Population distribution in 2000, regional environment A

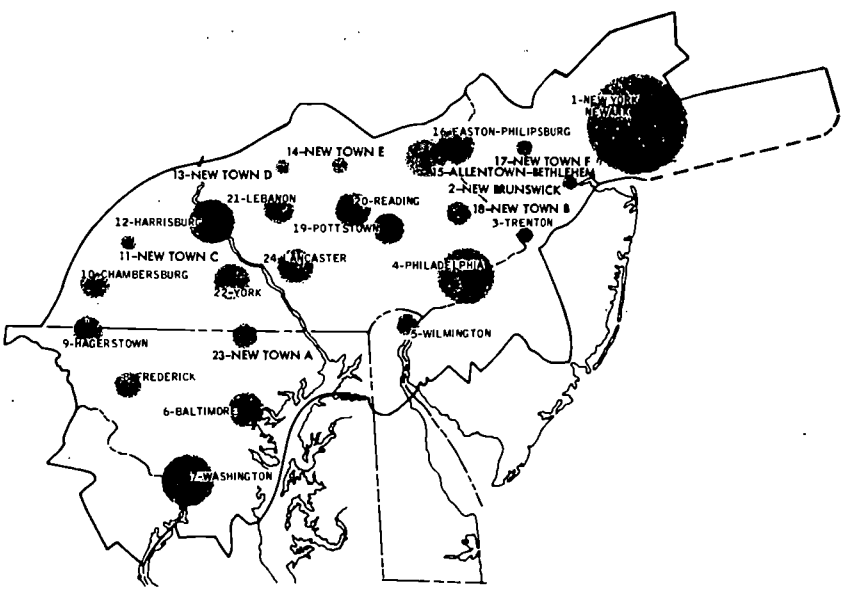


Fig. 3C--Population distribution in 2000, regional environment B

Fig. 3--Population distributions, 1970 and 2000

Table 3 gives the population limits for the six assumed city sizes and the outer radii of the three rings that characterize different parts of the city.*

Table 3

CITY SIZE DESCRIPTION

City Type	*Metropolitan Area Population (millions)*	*Outer Radius in Miles*		
		Ring 1	*Ring 2*	*Ring 3*
1	≥ 10	5.0	15	30
2	≥ 4 <10	3.33	10	20
3	≥ 1 <4	2.5	7.5	15
4	≥ .25 < 1	1.67	5	10
5	≥ .08 <.25	1.33	4	8
6	< .08	1.0	3	6

The inner ring represents the commercial core plus the heavily populated residential area immediately surrounding it. The middle ring represents the suburbanized area of primarily single family homes. The outer ring represents a mix of partly rural and partly exurban uses. Industries are scattered mostly through the inner two rings, contributing to an employment pattern which we shall describe. The ratios of the ring radii are the same for all city types, so we can assume that the relative population distributions of all cities are the same.

The population is further divided into *income groups*, assuming the following percentage distribution of people by annual family income:†

*Approximate radii for the city rings, fractions of the population in various income groups, fractions of each income group located in each city ring, and other similar information required throughout this volume in order to illustrate the methodology are the result of reviewing readily available statistics--the *Statistical Abstract of the United States*, and other sources--general reading, and the application of judgment. The estimates are thought to be reasonable, but are not based on formal studies.

†In this example, constant dollars are assumed throughout. We have not allowed for either growth in real per capita income or for any redistribution among income groups over time. These types of variations can be introduced if desired by inserting new assumptions and iterating the model.

	Income Group ($ thousands)	Percent of People
Poverty	< 4	10
Lower	≥ 4 <10	50
Middle	≥ 10<20	32
Upper	≥ 20	8

These groups are allocated to the rings in residential and in employment or job locations according to Table 4.

Table 4

RESIDENTIAL AND EMPLOYMENT DISTRIBUTIONS
OF INCOME GROUPS AMONG RINGS
(percent)

	Residential			Employment		
Income Group ($ thousands)	Ring 1	Ring 2	Ring 3	Ring 1	Ring 2	Ring 3
<4	65	15	20	60	20	20
≥4<10	40	20	40	45	45	10
≥10<20	25	60	15	60	35	5
≥20	25	50	25	75	23	2

To examine this distribution in another way, we construct Table 5, which gives the percent of the total city population in a given ring and a given income group. The sums across income groups give the total percentages of residence and employment by ring.

Table 5

DISTRIBUTION OF CITY POPULATION BY INCOME AND RING
(percent)

	Residential					Employment				
Ring	<$4K	≥$4<10K	≥$10<20K	≥$20K	Total	<$4K	≥$4<10K	≥$10<20K	≥$20K	Total
1	6.5	20.0	8.0	2.0	36.5	6.0	22.5	19.2	6.0	53.70
2	1.5	10.0	19.2	4.0	34.7	2.0	22.5	11.2	1.84	37.54
3	2.0	20.0	4.8	2.0	28.8	2.0	5.0	1.6	.16	8.76
Total	10.0	50.0	32.0	8.0	100.0	10.0	50.0	32.0	8.00	100.00

Using these figures we can construct a table of residence and job densities in each city type for each ring. We first assumed a typical population for a city in each type. The computations of residential density are made using the indicated total populations, the ring sizes shown in Table 3, and the ring percentages from Table 5. The computations of employment density are made in the same way except that we assume 37.8 percent of the population is employed, the figure for March 1969.* Table 6 shows the results.†

Table 6

RESIDENTIAL AND EMPLOYMENT DENSITIES

City Type	Assumed Population (in millions)	Residential (No./sq mi) Ring 1	Ring 2	Ring 3	Employment (No./sq mi) Ring 1	Ring 2	Ring 3
1	17.00	79,000	9,400	2,300	44,000	3,800	300
2	6.00	62,800	7,500	1,800	35,000	3,100	200
3	2.50	46,500	5,600	1,400	25,900	2,300	200
4	.60	25,100	3,000	700	14,000	1,200	100
5	.16	10,500	1,200	300	5,900	500	---
6	.04	4,700	600	100	2,600	200	---

Finally, Table 7 gives the percentage breakdown of the residential populace and the employment by income group for each ring. These can be used along with the residential densities to give the number of people by income class affected by a societal attribute within a known area.

*A refinement leading to greater accuracy would have this fraction vary by income level.

†This density information is used in Sec. V in calculating selected societal effects in physical quantitative terms. In the overall societal model described in Sec. VI, however, projected population information was incorporated for each individual city and varied by time period.

Table 7

INCOME BREAKDOWN BY RESIDENCE AND EMPLOYMENT IN EACH RING

(percent)

	Residence				Employment			
Ring	<$4K	≥$4<$10K	≥$10<$20K	≥$20K	<$4K	≥$4<$10K	≥$10<$20K	≥$20K
1	18	55	22	5	11	42	36	11
2	4	29	55	12	5	60	30	5
3	7	69	17	7	23	57	18	2

THE ALTERNATIVE MIXES OF MODES

Three alternative mixes of modes are considered in the example. The first, the base mix, is an evolutionary development of the current system, with no new modes added. Figure 4 shows the basic network of highways which serves the auto and the bus modes, plus the indicated air and rail service that was assumed to exist for scheduled passenger travel in 1970.

The two new mixes of modes assume a construction schedule for link improvements as follows, and is shown in Fig. 5:

1975-1980. New service is constructed on the New York to Washington chain of links; that is, the chains 1-2-3-4-5-6-7, where a chain is indicated by the sequence of nodes connected.

1980-1985. New service is constructed on Western extensions of high traffic potential; namely, the chains 6-23-22-12, 4-19-20-21-12, and 4-18-15.

1985-1990. New service is constructed on the remainder of a set of links in our network; namely, the chains 1-17-16-15-20-24-22-9, 15-14-13-12, 7-8-9-10-11-12, and 6-8.

The second mix of modes adds tracked air cushion vehicles (TACV) and short take-off and landing aircraft (STOL) service to the current mix, and is shown in Fig. 5B. In 1980 TACV is inaugurated on the New York to Washington chain. In 1985, TACV service is extended to the Philadelphia to Harrisburg chain, and the other two western extensions

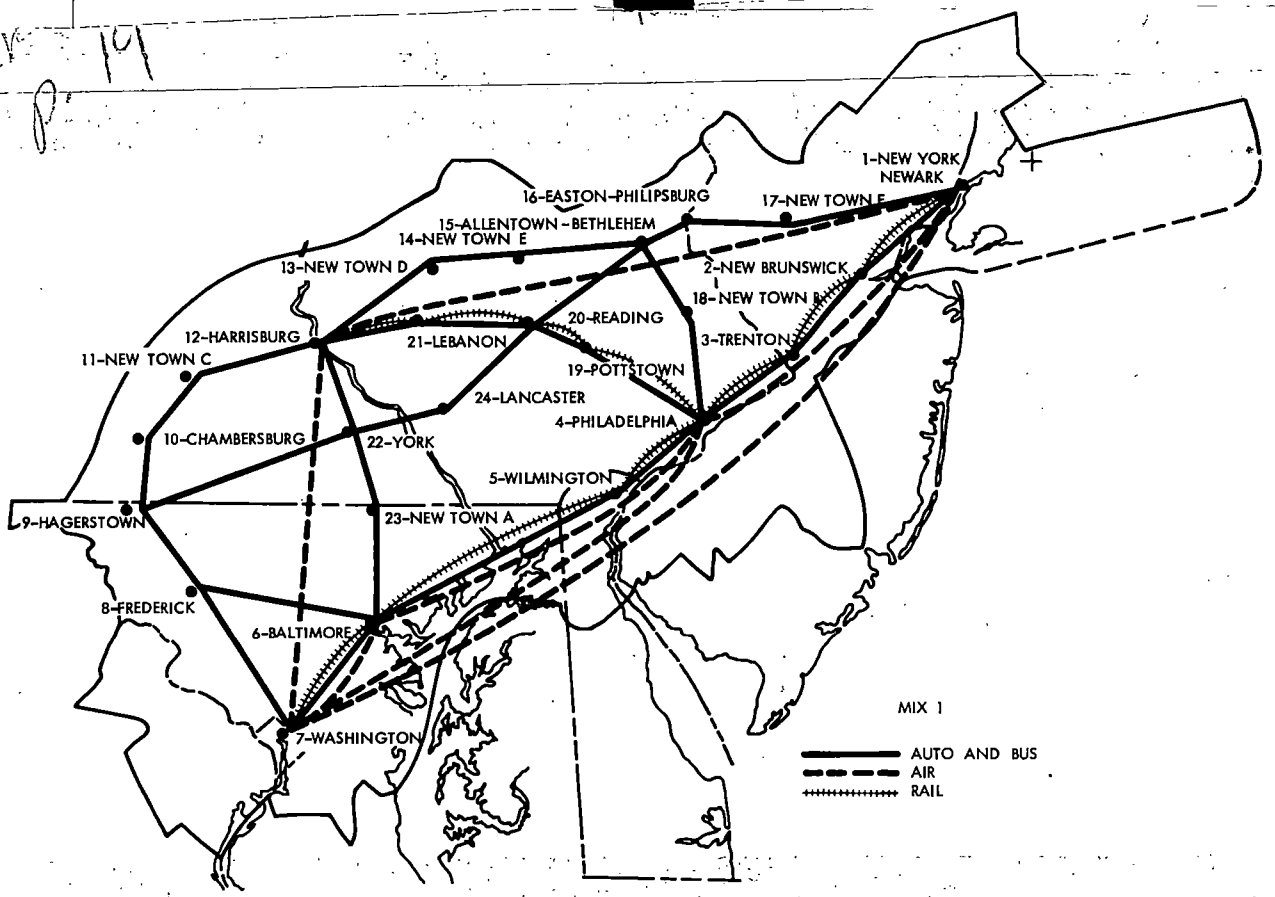


Fig. 4--The base mix of regional transportation service-1970

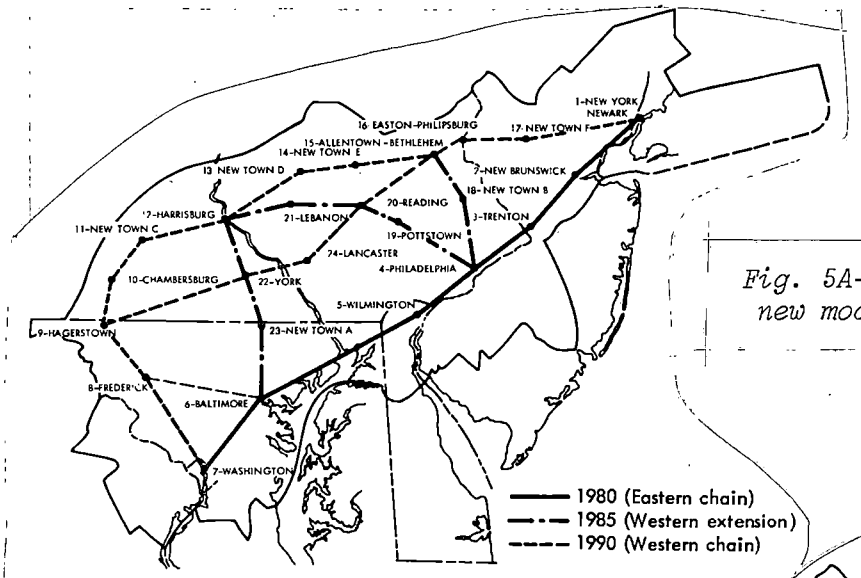


Fig. 5A--The schedule of new mode introduction

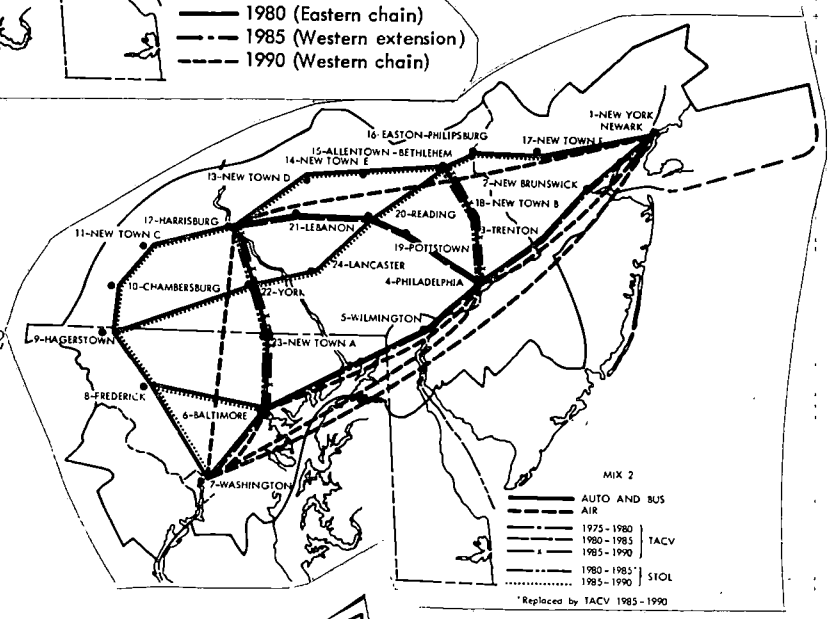


Fig. 5B--Time-phased introduction of mix 2 (addition of TACV/ STOL service)

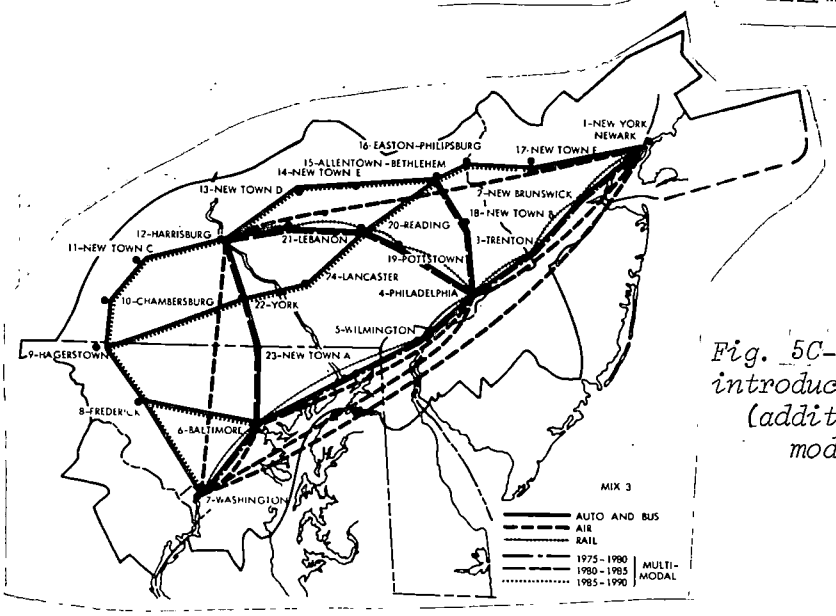


Fig. 5C--Time-phased introduction of mix 3 (addition of dual mode service)

Fig. 5--Transportation mixes

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have STOL service. In 1990, TACV service replaces STOL on these extensions and STOL serves the remaining links. In addition, conventional rail is phased out as soon as TACV service has started parallel to it.

The third mix of modes adds dual-mode (DM) service to the current mix, and is shown in Fig. 5C. In this case, conventional rail continues to operate at a low level. Since the technical concept of the dual-mode system is highly variable from one planning group to another, we should explain briefly the design we are using here.

Our objective for the dual-mode system is complete and rapid accessibility for areas of highly varying traffic densities. The system is composed of individual 2 to 4 person electric vehicles and a fixed track where the vehicles are computer-controlled for high speed flow. The vehicles can operate on the track or on today's surface streets. The track could replace some lanes of existing freeways or be independent of them. The vehicle speed would average 125 mph station-to-station on the track, and when operated on surface roads would have a maximum of 70 mph (however, they would go no faster than today's cars on ordinary city streets because of congestion).

The user's cost or fare per passenger mile would be 8 cents for the individual electric cars; the 8 cents is based on an assumption of 2.5 passengers per vehicle. Thus the operating cost of 20-cents per mile would be twice the 10-cents per mile of today's gasoline car. The safety would be comparable to today's automobiles, except that the individual car would be safer on its track than today's automobile on a freeway because of its automatic guidance.

Public ownership of individual cars would exist if necessary to achieve required safety standards. Possible options for the cars would be to buy one's own vehicle and get freqeunt (e.g., weekly) maintenance checks, or to rent the vehicles by the trip, day or week.*

*Our original plan was to include electric buses in the dual-mode service. Although not incorporated in our calculations, they might reasonably be added to provide more complete accessibility for all income groups. In such a case, possible options are the dial-a-bus system where a bus is routed along surface streets to pick up people who call and then uses the high-speed track when sufficiently loaded. Alternatively, a system of scheduled collection and distribution may be used. Also, we might assume bus fare would be 50 percent greater than the current intercity bus fare of 4 cents per mile.

Table 8 gives some sample passenger attributes for the different systems composing the mixes of modes. The speeds and costs are averages between line-haul stations; they do not include the access and egress portions of the trip. A complete list of performance values for the TACV mode, to illustrate the standard format that was used for the passenger attributes description, is given in the appendix as Table 65. Such a description was used in Secs. III and IV in computing user benefits.

Table 8

ILLUSTRATIVE DESCRIPTIVE INFORMATION ON EACH MODE

System	*Average Speed (mph)*	*Cost (¢ per pass. mi)*	*Safety (prob. of death per 10^8 pass. mi)*
Auto	50	4[a]	1.1[b]
Bus	50	4	0.2
Rail	70	6	0.1
Air (conventional)	100-250[c]	10	0.2
TACV	250	9	0.3
STOL	75-150[d]	11	0.4
Dual Mode	125	8[a]	0.4

[a] Based on 2.5 passengers per car.

[b] Accidents on limited-access highways only.

[c] Stage length 50-225 miles.

[d] Stage length 25-75 miles.

III. A SUMMARY OF REGION-WIDE USER BENEFITS

INTRODUCTION

This section describes a manual, or noncomputer-oriented, exercise in finding aggregate measures of user benefit over the network, over time, and for each mix of modes. The exercise provides rough estimates of worth or benefit in advance of the availability of a computer program that will produce greater accuracy by calculating worth on a link-by-link basis.

The approach is, first, to derive the regional demand by mode in passenger-miles over each time period. This is done by extrapolating from the known demand on one travel corridor using a highly simplified demand model. This demand is then multiplied by an estimated worth per passenger-mile on each mode. Thus, the total regional benefit for a given modal mix is estimated, and incremental calculations between pairs of mixes are performed.*

DERIVING REGIONAL DEMAND INFORMATION

As we stated in Vol. II [1], our methodology is designed so that demand information may either be fed in exogenously or calculated directly using the body of worth information developed in the method. In this first manual exercise, we actually would have preferred to take advantage of externally generated data but found no regional long-term demand projections available in appropriate form. It was, therefore, essential that we develop our own. The resulting crude demand package is based on what we believed were a set of reasonable assumptions. Since it is probable that other analysts may at times find themselves in a similar

*Points of reference in Vol. II for this section are (1) Sec. VI for a discussion of the analytic framework toward which we are striving--although in the discussion here we have avoided the complexity of analyzing individual network links; (2) Sec. IV for a discussion of identification, hierarchical structuring, and definition of attributes to be evaluated; and (3) Sec. V for methods of measurement and derivation of worth curves, as well as appropriate weighting of the attributes so that their values may be combined.

position, we now include a description of these assumptions and calculations. If the reader is only marginally concerned with how the demand information is to be derived. we suggest he proceed directly to the next subsection.

Our need was for estimates of region-wide demand for intercity transportation expressed in millions of passenger-miles for each regional environment R, 5-year time period t, mix-of-modes M, mode m, and income group g. To derive these estimates, we used 1965-70 annual demand data for New York-Washington through trips (by each mode in the current mix) as a base point. We prepared the estimates using

1. Population projections for the cities in the region.
2. A percentage breakdown of the population by income groups.
3. Network mileage by mode in each of three regional sections during each time period.
4. Sets of travel propensity factors by mode, assuming given modal mixes, income groups, and time periods.
5. A link flow factor to modify the information for New York-Washington through trips to total travel for all origin-destination pairs in the New York-Washington chain, and, hence, to the network as a whole.

Manual calculation was facilitated by developing a series of appropriate estimating ratios based on the above-mentioned data. Again, information was produced in millions of passenger-miles for each 5-year period. The calculations are described precisely in Eq. (1).

$$D_{gmt} = \sum_{R'} \left[\frac{P_{R't}}{P_{R'0t0}} \times \frac{d_{m'R't}}{d_{R'0't0}} \right] \times h(g) \times p_{gm't'} \times K \qquad (1)$$

where R' = a regional or network section--e.g., the Eastern Chain, the Western Extension, or the Western Chain,

$P_{R't}/P_{R'0t0}$ = *relative population*--i.e., the ratio of the population section in a given regional environment and time period to the population in the base section--i.e., the Eastern Chain in 1970,

d = the mileage in a network section,

$d_{m'R't}/d_{R'0_t0}$ = the *relative mileage*--i.e., the ratio of the mileage for a given mode in a given mix of modes, network section, and time period, to the mileage in the base section in 1970,

$h(g)$ = the fraction of the population in each income group,

$p_{gm't'}$ = a travel propensity factor indicating the number of trips an individual will make by a given mode m' within a given modal mix during one year t'; these factors were derived using estimated 1970 New York-Washington through trips by each mode as a base,

K = a constant incorporating a link flow factor of 5, a time period of 5 years, the mileage in the base section of 220 miles, and 10^6 to reflect the fact that population statistics used in deriving relative population were in millions ($5 \times 5 \times 220 \times 10^6 = 5500 \times 10^6$). Demand from other regions flowing into and out of the region is assumed to be included in the link flow-factor.

Information required in the calculation is detailed below.

Relative population data, $P_{R't}/P_{R'0_t0}$, are derived using the mid-period population projections of Table 9, and are provided in Table 10.

Data on relative mileage, $d_{m'R't}/d_{R'0_t0}$, are derived from the basic mileage information presented in Table 11. It is combined with the relative population data in the form of a passenger/miles generator

$$\sum_{R'} \left[\frac{P_{R't}}{P_{R'0_t0}} \times \frac{d_{m'R't}}{d_{R'0_t0}} \right],$$

in Table 12.

Table 9

POPULATION AT MID-PERIOD

(In millions)

City	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
Environment A						
1	16.74	18.04	19.44	20.94	22.55	24.23
2	.23	.25	.27	.29	.31	.33
3	.34	.37	.40	.43	.46	.50
4	5.02	5.41	5.83	6.28	6.77	7.29
5	.53	.58	.63	.68	.73	.78
6	2.15	2.31	2.49	2.69	2.89	3.12
7	3.16	3.57	4.04	4.58	5.18	5.86
8	.08	.09	.09	.10	.10	.11
9	.10	.11	.11	.12	.13	.13
10	.10	.11	.11	.12	.13	.13
11	---	---	---	---	---	---
12	.42	.45	.46	.49	.51	.54
13	---	---	---	---	---	---
14	---	---	---	---	---	---
15	.37	.40	.41	.43	.45	.47
16	.18	.19	.20	.21	.22	.24
17	---	---	---	---	---	---
18	---	---	---	---	---	---
19	.14	.15	.16	.17	.18	.18
20	.30	.31	.33	.35	.36	.38
21	.10	.11	.11	.12	.13	.13
22	.33	.35	.36	.38	.40	.42
23	---	---	---	---	---	---
24	.31	.32	.34	.36	.38	.39
25[a]	1.03	1.08	1.13	1.19	1.25	1.32
Environment B						
1	16.56	17.41	17.61	17.18	16.75	16.34
2	.22	.24	.24	.23	.23	.22
3	.34	.35	.35	.34	.33	.33
4	4.97	5.22	5.28	5.16	5.03	4.90
5	.53	.56	.56	.55	.54	.53
6	2.12	2.23	2.26	2.20	2.15	2.09
7	3.13	3.46	3.66	3.76	3.86	3.96
8	.09	.12	.18	.30	.49	.78
9	.12	.16	.23	.37	.61	.98
10	.12	.16	.23	.37	.61	.98
11	---	---	---	.04	.09	.22
12	.46	.56	.76	1.11	1.63	2.39
13	---	---	---	.04	.09	.22
14	---	---	---	.04	.09	.22
15	.40	.48	.66	.96	1.41	2.08
16	.18	.19	.20	.21	.22	.24
17	---	---	---	---	---	---
18	---	---	---	---	---	---
19	.14	.15	.16	.17	.18	.18
20	.30	.31	.33	.35	.36	.38
21	.10	.11	.11	.12	.13	.13
22	.33	.35	.36	.38	.40	.42
23	---	---	---	---	---	---
24	.31	.32	.34	.36	.38	.39
25[a]	1.03	1.08	1.13	1.19	1.25	1.32

[a]Rural areas.

Table 10

RELATIVE POPULATION FACTORS $\frac{P_{R,t}}{P_{R,0}}$

	Time Period[a]					
	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
Regional Environment A:						
Eastern Chain	1.040	1.130	1.230	1.340	1.450	1.560
Western Ext	.047	.050	.053	.056	.059	.062
Western Chain	.042	.044	.047	.050	.052	.055
Regional Environment B:						
Eastern Chain	1.030	1.090	1.110	1.090	1.070	1.050
Western Ext	.052	.080	.110	.150	.200	.310
Western Chain	.042	.050	.080	.120	.200	.310

[a]For any readers who may be bothered by the apparently overlapping time periods shown in many of the tables in this volume, the 5-year periods are in terms of Federal fiscal years, for example, the period 1970-1975 runs from July 1, 1970 to June 30, 1975.

Table 11

NETWORK MILEAGE BY MODE AND TIME PERIOD

Mode	1970-75			1975-80			1980-85			1985-90			1990-95			1995-2000		
	E	Ext	W	E	Ext	W	E	Ext	W	E	Ext	W	E	Ext	W	E	Ext	W
Mix 1 (base mix)																		
Bus and auto	220	221	514	220	221	514	220	221	514	220	221	514	220	221	514	220	221	514
Rail	220	101	0	220	101	0	220	101	0	220	101	0	220	101	0	220	101	0
Air	100	50	0	100	50	0	100	50	0	100	50	0	100	50	0	100	50	0
Mix 2 (TACV/STOL added)																		
Bus and auto	220	221	514	220	221	514	220	221	514	220	221	514	220	221	514	220	221	514
Rail	220	101	0	220	101	0	0	101	0	0	0	0	0	0	0	0	0	0
Air	100	50	0	100	50	0	100	50	0	100	50	0	100	50	0	100	50	0
TACV	0	0	0	0	0	0	220	0	0	220	101	0	220	221	0	220	221	0
STOL	0	0	0	0	0	0	0	0	0	0	120	0	0	0	514	0	0	514
Mix 3 (dual-mode added)																		
Bus and auto	220	221	514	220	221	514	220	221	514	220	221	514	220	221	514	220	221	514
Rail	220	101	0	220	101	0	220	101	0	220	101	0	220	101	0	220	101	00
Air	100	50	0	100	50	0	100	50	0	100	50	0	100	50	0	100	50	0
Dual mode	0	0	0	0	0	0	220	0	0	220	221	0	220	221	514	220	221	514

NOTE: "Air" implies conventional jet transport; "STOL" implies a small plane that requires a short runway and is intended for short, low-density routes; E = "Eastern Chain"; Ext = "Western Extension"; W = "Western Chain"

Table 12

PASSENGER MILES GENERATOR

$$\sum_{R'} \left[\frac{P_{R't}}{P_{R'0t0}} \times \frac{d_{m'R't}}{d_{R'0t0}} \right]$$

	Environment A						Environment B					
	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
Mix 1												
Bus and auto	1.19	1.28	1.39	1.51	1.63	1.75	1.17	1.28	1.44	1.61	1.84	2.09
Rail	1.06	1.15	1.25	1.37	1.48	1.59	1.04	1.12	1.19	1.25	1.26	1.19
Air	.49	.53	.58	.63	.68	.73	.48	.52	.55	.58	.59	.55
Mix 2												
Bus and auto	1.19	1.28	1.39	1.51	1.63	1.75	1.17	1.28	1.44	1.61	1.84	2.09
Rail	1.06	1.15	.02	0	0	0	1.04	1.12	.05	0	0	0
Air	.49	.53	.58	.63	.68	.73	.48	.52	.55	.58	.59	.55
TACV	0	0	1.23	1.37	1.51	1.62	0	0	1.14	1.25	1.37	1.36
STOL	0	0	0	.03	.12	.13	0	0	0	.08	.47	.73
Mix 3												
Bus and auto	1.19	1.28	1.39	1.51	1.63	1.75	1.17	1.28	1.44	1.61	1.84	2.09
Rail	1.96	1.15	1.25	1.37	1.48	1.59	1.04	1.12	1.19	1.25	1.26	1.19
Air	.49	.53	.58	.63	.68	.73	.48	.52	.55	.58	.59	.55
Dual mode	0	0	1.23	1.40	1.63	1.75	0	0	1.14	1.33	1.84	2.09

Fractions of the population in each income group, $h(g)$, were provided in Sec. II as follows:

	Annual Family Income	*h(g) (fraction)*
Poverty	<$4K	.10
Lower	≥$4-$10K	.50
Middle	≥$10-$20K	.32
Upper	≥$20K	.08

Travel propensities are given in Table 13. They are for each mode within three different mixes of modes and for the four income groups. The factors are illustrative but satisfy our intuition concerning the attractiveness of the different modes to each income group. Also, they are calibrated so that

$$\sum_g [Dmt^{\rho} \times h(g)]$$

Table 13

TRAVEL PROPENSITY FACTORS

Income Group	*Factors*					
	Auto	*Bus*	*Rail*	*Air*	*TACV/ STOL*	*Dual-Mode*
Mix 1 (base mix), 1970-2000; also Mixes 2 and 3, 1970-80						
P	.84	.84	.27	0		
L	2.24	.57	.42	.27		
M	2.24	.42	.84	2.52		
U	.84	0	.84	4.47		
Mix 2 (TACV/STOL added), 1980-2000						
P	.88	.88		0	.19	
L	2.18	.55		.09	.73	
M	1.64	.36		.91	3.63	
U	.55	0		2.54	3.63	
Mix 3 (dual-mode added), 1980-2000						
P	.73	.84	.19	0		.27
L	1.45	.57	.36	.19		1.18
M	1.09	.42	.36	1.36		4.09
U	.36	0	.27	3.27		3.63

for the current mix generates the following estimated 1970 annual passenger demand between New York and Washington:

	Millions of trips
Rail	0.6
Auto	2.0
Bus	0.5
Air	1.3
Total	4.4

The total 5-year passenger mileages predicted by the above method for each time period, group, and mode, assuming each regional environment and modal mix are shown in Table 14. It is obvious that these demands were obtained by a crude procedure; hence, little emphasis should be given to outputs based on these numbers. What is intended here is to illustrate a methodology in which demand calculations are an input or subroutine to be derived in the best possible way, given limited time and resources.

COMPUTATION OF WORTH

The next step in the methodology is to obtain basic worth information. Doing this assumes the availability of (a) a structured hierarchy of attributes, (b) physical measures of each attribute for each of the transportation modes being evaluated, and (c) either generalized worth curves relating physical values with worth values or direct worth estimates for each attribute of each mode.*

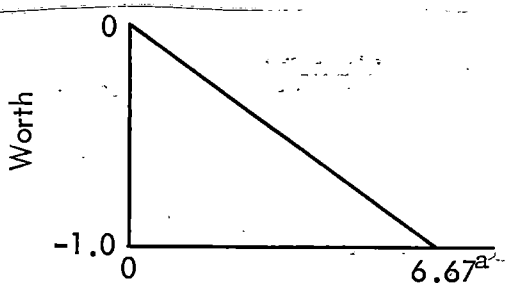
Worth curves used in this exercise are specified in the appendix as Table 66. Physical performance values are illustrated for the TACV mode only in Table 65. To reduce the computational complexity of the exercise, we assumed that all worth curves could be defined in linear fashion as follows:

*Derivation of these steps is described in Secs. IV and V of Vol. II and also was the primary emphasis of the first phase of our research documented in Ref. 10.

Table 14

5-YEAR DEMAND IN MILLIONS OF PASSENGER MILES

Mode	Income Group	Regional Environment A 1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000	Regional Environment B 1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
Mix 1													
Auto	P	500	500	500	700	800	800	500	600	700	700	800	1000
	L	7300	7900	8600	9300	10,000	10,800	7200	7900	8900	9900	11,300	12,800
	M	4700	5000	5500	5900	6400	6900	4600	5000	5670	6350	7250	8220
	U	400	500	500	600	700	700	400	500	600	600	700	800
Bus	P	500	600	600	700	800	800	500	600	700	700	800	1000
	L	1800	2000	2200	2300	2500	2700	1800	2000	2200	2500	2900	3200
	M	900	900	1000	1100	1200	1300	900	900	1100	1200	1400	1500
	U	0	0	0	0	0	0	0	0	0	0	0	0
Rail	P	200	200	200	200	200	300	200	200	200	200	200	200
	L	1200	1300	1400	1600	1700	1800	1200	1300	1400	1400	1400	1300
	M	1600	1700	1800	2000	2200	2300	1500	1600	1800	1800	1800	1800
	U	400	400	500	600	600	700	500	500	500	500	500	500
Air	P	0	0	0	0	0	0	0	0	0	0	0	0
	L	400	400	400	500	500	500	400	400	400	400	400	400
	M	2200	2400	2600	2800	3000	3200	2100	2300	2400	2600	2600	2400
	U	1000	1000	1100	1200	1300	1400	1000	1000	1100	1100	1200	1100
Mix 2													
Auto	P	500	500	700	700	800	800	540	590	690	770	880	1000
	L	7300	7900	8300	9100	9800	10,500	7200	7870	8640	9660	11,040	12,540
	M	4700	5000	4000	4400	4700	5000	4610	5040	4150	4640	5360	6020
	U	400	500	300	400	400	400	430	470	350	390	440	500
Bus	P	500	600	700	700	800	800	540	590	690	770	880	1000
	L	1800	2000	2100	2300	2500	2600	1820	1980	2160	2420	2760	3140
	M	900	900	900	1000	1000	1100	860	940	920	1030	1180	1340
	U	0	0	0	0	0	0	0	0	0	0	0	0
Rail	P	200	200	0	0	0	0	160	170	0	0	0	0
	L	1200	1300	0	0	0	0	1200	1290	0	0	0	0
	M	1600	1600	0	0	0	0	1530	1650	0	0	0	0
	U	400	400	0	0	0	0	380	410	0	0	0	0
Air	P	0	0	0	0	0	0	0	0	0	0	0	0
	L	400	400	100	200	200	200	360	390	140	140	150	140
	M	2200	2400	900	1000	1100	1200	2130	2310	880	930	940	880
	U	1000	1000	600	700	800	800	940	1020	620	650	660	620
TACV	P	0	0	100	100	190	190	0	0	110	120	130	140
	L	0	0	2500	2740	3060	3240	0	0	2280	2500	2710	2720
	M	0	0	7900	8800	9610	10,400	0	0	7300	8000	8770	8710
	U	0	0	2000	2150	2410	2600	0	0	1820	2750	2190	2170
STOL	P	0	0	0	0	10	10	0	0	0	10	50	70
	L	0	0	0	60	240	260	0	0	0	160	970	1460
	M	0	0	0	190	790	830	0	0	0	510	3010	4670
	U	0	0	0	50	190	200	0	0	0	180	750	1170
Mix 3													
Auto	P	500	500	600	600	700	700	540	590	580	640	740	840
	L	7300	7900	5600	6000	6500	7000	7200	7870	5760	6440	7360	8360
	M	4700	5000	2700	2900	3100	3400	4610	5040	2760	3090	3530	4010
	U	400	500	200	200	300	300	430	470	230	260	290	330
Bus	P	500	600	600	700	800	800	540	590	660	740	850	960
	L	1800	2000	2200	2300	2500	2700	1820	1980	2230	2500	2850	3240
	M	900	900	1000	1100	1200	1300	860	990	1060	1180	1340	1540
	U	0	0	0	0	0	0	0	0	0	0	0	0
Rail	P	200	200	100	100	100	200	160	170	120	130	130	120
	L	1200	1300	1300	1400	1500	1600	1200	1290	1190	1250	1260	1190
	M	1600	1700	800	900	900	1000	1530	1650	760	800	810	760
	U	400	400	200	200	200	300	380	410	140	150	150	140
Air	P	0	0	0	0	0	0	0	0	0	0	0	0
	L	400	400	300	300	300	400	360	390	280	290	300	280
	M	2200	2400	1400	1500	1600	1800	2130	2310	1320	1390	1420	1320
	U	1000	1000	800	900	1000	1100	940	1020	790	840	850	790
Dual-	P	0	0	200	200	200	300	0	0	170	200	280	310
Mode	L	0	0	4000	4600	5300	5700	0	0	3710	4330	5980	6800
	M	0	0	8900	10,100	11,800	12,600	0	0	8200	9580	13,250	15,050
	U	0	0	2000	2200	2600	2800	0	0	1820	2130	2940	3340



[a]See Table 66.

Also, the curves are specified such that worth values have been multiplied by the relative attribute weights for middle income persons traveling on business. The weights are so specified that they add to 1.0.

As a base point we chose to calculate summary worth information for the line-haul portion of a New York to Washington trip. Time and cost inputs* for this calculation were

	Auto	*Bus*	*Rail*	*Air*	*TACV*	*STOL*	*Dual-Mode*
Time, hr	4.5	4.2	3.0	1.17	0.9	1.25	1.68
Cost, $	8.50[a]	8.25	12.75	18.00	18.00	23.10	16.80[a]

[a]Assumes 2-1/2 persons per vehicle.

Other physical performance information was input using formats similar to Table 65 for each of the modes. The results of the calculation are shown in Table 15 summarized to the level of five major user attributes: travel cost, travel time, safety and security, convenience, and comfort.

As explained in Sec. VI of Volume II, it is most natural to construct most worth curves for user attributes on a 0 to -1.0 scale--i.e., it is natural for a traveler to assess alternative modes in terms of minimizing travel time, cost, safety hazards, inconvenience, and discomfort. On the other hand, interpreting the results is easier if values are in positive terms, especially since this information is to be

*Derivation of worth curves for travel time and travel cost is discussed in Sec. IV.

Table 15

SUMMARY WORTH INFORMATION OF A NEW YORK TO WASHINGTON TRIP FOR A MIDDLE INCOME PERSON TRAVELING ON BUSINESS

Line-haul Portion

Attribute	*Auto*	*Bus*	*Rail*	*Air*	*TACV*	*STOL*	*Dual-Mode*
Cost	-.170	-.165	-.255	-.360	-.360	-.462	-.326
Time	-.665	-.630	-.400	-.175	-.135	-.187	-.252
Safety & Security	-.215	-.261	-.201	-.142	-.135	-.153	-.083
Convenience	-.406	-.248	-.355	-.421	-.355	-.421	-.025
Comfort	-.068	-.465	-.147	-.183	+.065[a]	-.183	+.039[a]
Total	-1.524	-1.769	-1.358	-1.281	-.920	-1.406	-.647

[a]Positive numbers indicate that positive factors slightly outweighed negative factors for these entries.

used in several subsequent calculations. Therefore, we next transformed the scales by adding +1.0 to each major attribute value in Table 15; for example, the worth value for cost of the bus mode became +.835.*

Now, it is reasonable to assume that other groups of users have different relative weights on the five major attributes. Using the deterministic weighting scheme discussed in Sec. V of Vol. II we divided 1000 points among these attributes for the different groups. These weights represent the authors' judgment of how different groups feel, since sufficient resources to design and implement a sample survey were lacking. Then, for each of our four groups, the worth score on each major attribute (e.g., convenience) was multiplied by an "adjustment factor" which was the ratio of the weight for this group to the weight for the reference group, namely, middle income persons traveling on business.

Table 16 shows the weights for four income groups, averaged over business and pleasure purposes, and for the reference group. It also presents the adjustment factors.

*In a more detailed calculation, it would have been more accurate to add +1.0 at the level of each individual attribute.

Table 16

MAJOR ATTRIBUTE WEIGHTS

Attribute	*Middle Income or Business*	*Average Business and Pleasure* P	L	M	U	*Adjustment Factors* P	L	M	U
Cost	100	350	225	150	100	3.5	2.25	1.5	1.0
Time	200	50	125	150	188	.25	.625	.75	.937
Safety	500	500	500	500	500	1.0	1.0	1.0	1.0
Convenience	125	50	100	125	137	.4	.8	1.0	1.1
Comfort	75	50	50	75	75	.667	.667	1.0	1.0

NOTE: *P* = Poverty group (<$4K); *L* = Lower group (≥$4<$10K); *M* = Middle group (≥$10<$20K); *U* = Upper group (≥$20K).

Table 17 gives the results of these adjustment factors applied to the worths of Table 15, as modified by the positive transformation. For example, the cost worth of bus travel for the poverty group is obtained by adding 1 to -.165 from Table 15, giving .835, and then multiplying by 3.5 from Table 16; the result is 2.923.

Dividing the worth scores of the New York-Washington trip by its distance of 220 miles (from Table 11) gives a per-mile worth score for each mode and each user group.*

When this per-mile worth information is multiplied by the passenger-mile demand information given in Table 14, we obtain an estimate of the total line-haul user benefit. This benefit is summarized by income group, for each regional environment and mix in each time period, in Table 18. A more detailed listing of line-haul user benefits, by mode and major attribute, is available in a computer-generated table as illustrated in Table 19 for a single mode within a given modal mix. A sample detailed output for all six cases is provided in the appendix as Table 67.

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*After building blocks of this sort have been constructed a few times and tested for reasonableness, it should be feasible to use these in a variety of subsequent exercises, rather than repeating the detailed lower level attribute calculations on every occasion. The more detailed procedures continue to be important, however, if interaction with the engineering design process is an objective.

Table 17

WORTH INFORMATION FOR THE NEW YORK TO WASHINGTON TRIP BY INCOME GROUP

Line-haul Portion

Attribute	*Auto*	*Bus*	*Rail*	*Air*	*TACV*	*STOL*	*DM*
Poverty group (<$4,000)							
Cost	2.905	2.923	2.608	2.240	2.240	1.883	2.359
Time	.084	.093	.150	.206	.056	.203	.187
Safety	.785	.739	.799	.858	.865	.847	.917
Convenience	.238	.301	.258	.232	.258	.232	.390
Comfort	.622	.357	.569	.545	.710	.545	.693
Total	4,634	4.413	4.384	4.081	4.129	3.710	4.546
Lower income group ($4,000-$10,000)							
Cost	1.868	1.879	1.676	1.440	1.440	1.211	1.517
Time	.209	.231	.375	.516	.540	.508	.468
Safety	.785	.739	.799	.858	.865	.847	.917
Convenience	.475	.602	.516	.463	.516	.463	.780
Comfort	.622	.357	.569	.545	.710	.545	.693
Total	3.959	3.808	3.935	3.822	4.071	3.574	4.375
Middle income group ($10,000-$20,000)							
Cost	1.245	1.253	1.118	.960	.960	.807	1.011
Time	.251	.278	.450	.619	.649	.610	.561
Safety	.785	.739	.799	.858	.865	.847	.917
Convenience	.594	.752	.645	.579	.645	.579	.975
Comfort	.932	.535	.853	.817	1.065	.817	1.039
Total	3.807	3.557	3.865	3.833	4.184	3.660	4.503
Upper income group (>$20,000)							
Cost	.830	.835	.745	.640	.640	.538	.674
Time	.314	.347	.562	.773	.811	.762	.701
Safety	.785	.739	.799	.858	.865	.847	.917
Convenience	.653	.827	.710	.637	.710	.637	1.073
Comfort	.932	.535	.853	.817	1.065	.817	1.039
Total	3.514	3.283	3.669	3.725	4.091	3.601	4.404

Table 18

TOTAL WORTH SCORES (5-YEAR BENEFIT INDICES)

Line-haul Portion of Trips Only

	Year					
	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
Regional Environment A						
Mix 1 (base)						
P	25	27	27	33	37	39
L	191	207	225	245	262	282
M	162	173	188	204	232	237
U	30	32	35	40	43	47
Total	408	439	475	521	574	605
Mix 2 (TACV/STOL added)						
P	25	27	31	31	37	37
L	191	207	234	259	284	302
M	162	173	250	280	313	337
U	30	32	52	59	68	72
Total	408	439	567	629	701	747
Mix 3 (Dual-mode added)						
P	25	27	31	33	37	41
L	191	207	247	270	298	322
M	162	173	284	317	358	387
U	30	32	60	66	77	85
Total	408	439	622	686	770	835
Regional Environment B						
Mix 1						
P	25	28	33	33	37	45
L	189	206	230	253	286	316
M	158	172	189	206	225	240
U	29	32	37	37	40	40
Total	401	438	489	529	588	641
Mix 2						
P	25	28	30	34	39	45
L	189	206	238	267	315	357
M	158	172	241	274	345	384
U	29	32	50	71	71	78
Total	401	438	559	646	770	864
Mix 3						
P	25	28	31	35	41	46
L	189	206	242	273	329	368
M	158	172	269	307	393	439
U	29	32	56	64	80	88
Total	401	438	598	679	843	941

Table 19

LINE-HAUL WORTH: REGIONAL ENVIRONMENT B, MIX 2

Detailing Mode, Income Group, and Major Attribute

In Millions of Worth Points

	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
AUTO						
Poverty ($ 0 - 4K)						
Safety/Secur	1.9	2.1	2.5	2.7	3.1	3.6
Convenience	.6	.6	.7	.8	1.0	1.1
Comfort	1.5	1.7	2.0	2.2	2.5	2.8
Subtotal	4.0	4.4	5.2	5.8	6.6	7.5
Time	.2	.2	.3	.3	.3	.4
Cost	7.1	7.8	9.1	10.2	11.6	13.2
Subtotal	7.3	8.0	9.4	10.5	12.0	13.6
Total	11.4	12.4	14.5	16.2	18.5	21.1
Lower ($ 4K - 10K)						
Safety/Secur	25.7	28.1	30.8	34.5	39.4	44.8
Convenience	15.6	17.0	18.7	20.9	23.8	27.1
Comfort	20.4	22.3	24.5	27.3	31.2	35.5
Subtotal	61.6	67.4	74.0	82.7	94.5	107.3
Time	6.8	7.5	8.2	9.2	10.5	11.9
Cost	61.1	66.8	73.4	82.0	93.7	106.5
Subtotal	68.0	74.3	81.6	91.2	104.2	118.4
Total	129.6	141.7	155.5	173.9	198.7	225.7
Middle ($ 10K - 20K)						
Safety/Secur	16.5	18.0	14.8	16.6	19.1	21.5
Convenience	12.4	13.6	11.2	12.5	14.5	16.3
Comfort	19.5	21.4	17.6	19.7	22.7	25.5
Subtotal	48.5	53.0	43.6	48.8	56.3	63.3
Time	5.3	5.7	4.7	5.3	6.1	6.9
Cost	26.1	28.5	23.5	26.3	30.3	34.1
Subtotal	31.3	34.3	28.2	31.6	36.4	40.9
Total	79.8	87.2	71.8	80.3	92.8	104.2
Upper (>$20K)						
Safety/Secur	1.5	1.7	1.2	1.4	1.6	1.8
Convenience	1.3	1.4	1.0	1.2	1.3	1.5
Comfort	1.8	2.0	1.5	1.7	1.9	2.1
Subtotal	4.6	5.1	3.8	4.2	4.7	5.4
Time	.6	.7	.5	.6	.6	.7
Cost	1.6	1.8	1.3	1.5	1.7	1.9
Subtotal	2.2	2.4	1.8	2.0	2.3	2.6
Total	6.9	7.5	5.6	6.2	7.0	8.0
TOTAL	227.6	248.8	247.5	276.6	317.1	359.0

From the data in Table 18, differences can be found in the benefits from different modal mixes in a given regional environment, and in the benefits from a given modal mix assuming different regional environments. These benefit differences can be decomposed by mode, income group and major attribute, using the more detailed tables. Sensitivity analyses involving these benefit differences are illustrated in Sec. VI of this volume.

SUMMARY

A region-wide computation of user benefits has been described, and the results given for our basic example. This computation was performed without computer assistance except for the final steps of multiplying two data files. A potentially more accurate computerized and network-oriented method is described in the next section. Access-egress considerations are also addressed at that point.

IV. A NETWORK-ORIENTED MIX OF MODES ANALYSIS OF USER BENEFITS*

INTRODUCTION

This section describes how a series of evolving computer routines can be used in a detailed, network-oriented analysis of user benefits. The first routine starts simply and analyzes a single user attribute--travel time--over a transportation network involving a single travel mode. Second, the capability is extended to consider a network with more than one mode. Third, the methodology is further extended to consider multiple user attributes as well as a mix of modes on individual origin-destination pairs in a network. We demonstrate how both link attributes and chain-of-link attributes can be measured and incorporated into the analysis. A method for handling the access and egress portions of overall trips also is illustrated. Next, optimal paths through a network are determined incorporating both multiple attributes and mixes of modes. Then link flows and demand are estimated. Finally, demand information is combined with worth information for an aggregate measure of user benefit.

Obviously, introducing the network dimension explicitly into the benefit evaluation process considerably increases its complexity. The procedures illustrated in this section attempt to sort out the various steps involved and suggest logical ways of proceeding toward a workable model. The entire discussion should be viewed in the light in which it was developed--i.e., as a series of exploratory excursions into a very complex methodological problem area.

SINGLE ATTRIBUTE--SINGLE MODE

The first routine is devoted to developing a useful format for specifying a transportation network and beginning a preliminary analysis of that network. To accomplish this, 24 network nodes shown in Fig. 4 are assumed. Table 20 identifies the nodes, indicates their geographical coordinates, and categorizes each node into one of six city

*Further discussion of the methodology illustrated in this section is found in Sec. VI of Vol. II.

Table 20

NODE SPECIFICATION

Number	*Name*	*Latitude*	*Longitude*	*City Type*
1	New York/Newark	40° 45'	73° 59'	1
2	New Brunswick	40° 30'	74° 27'	5
3	Trenton	40° 13'	74° 46'	4
4	Philadelphia	39° 56'	75° 09'	2
5	Wilmington	39° 44'	75° 33'	4
6	Baltimore	39° 17'	76° 37'	3
7	Washington	38° 53'	77° 02'	3
8	Frederick	39° 25'	77° 25'	5
9	Hagerstown	39° 39'	77° 43'	5
10	Chambersburg	39° 56'	77° 39'	5
11	New Town C	40° 10'	77° 24'	6
12	Harrisburg	40° 15'	76° 53'	4
13	New Town D	40° 33'	76° 23'	6
14	New Town E	40° 35'	76° 01'	6
15	Allentown/Bethlehem	40° 36'	75° 25'	4
16	Easton/Phillipsburg	40° 41'	75° 12'	5
17	New Town F	40° 40'	74° 45'	6
18	New Town B	40° 20'	75° 12'	6
19	Pottstown	40° 15'	75° 40'	5
20	Reading	40° 20'	75° 55'	4
21	Lebanon	40° 21'	76° 25'	5
22	York	39° 58'	76° 43'	4
23	New Town A	39° 42'	76° 38'	6
24	Lancaster	40° 03'	76° 18'	4

types based on population size. The city types were described in Table 3. Travel service is confined in this routine to a track-type--e.g., railroad--mode operating on the same 31 links as shown for the highway mode in Fig. 4. The links also are classified into eight link types based on estimates of travel density (high, H; medium, M; or low, L), construction complexity (mountainous, CM; level, CL; or urban, CU), and scenic beauty along each link (scenic, S; average, A; or ugly, U) as follows:*

Link Type	*Travel Density*	*Construction Complexity*	*Scenic Beauty*
1	H	CU	U
2	M	CM	S
3	H	CU	A

*Although we had intended additional uses for this classification, thus far we have used only portions of it specifically in estimating link circuity and in analyzing societal impacts. Possible combinations

Link Type	*Travel Density*	*Construction Complexity*	*Scenic Beauty*
4	M	CU	A
5	L	CM	S
6	L	CL	S
7	M	CL	S
8	H	CL	A

Origin and destination nodes* for each link, the length of each link, and the link type classifications are all shown in Table 21.

The first analysis of the network was to compute the total trip time for travel between any pair of nodes. Several additional assumptions had to be made. The railroad was assumed to average 60 miles per hour along all links except in the vicinity of a city. An accelerate/decelerate function was devised to account for the fact that a train must normally slow down when passing through each node in a total trip. The accelerate/decelerate function simply specified an additional increment of travel time for each intermediate city as a function of its node type. That function was as follows:

Node Type	*Accelerate/Decelerate Time Increment (min.)*
1	30
2	25
3	20
4	15
5	10
6	5

Obviously, the larger the city, the longer it takes to slow down and then speed up to the average velocity. One might well argue that the accelerate/decelerate function was not very exact. For the purpose of the exercise, however, it was felt that the function reflected city size, and the function could always be replaced with a more sophisticated version based on the technology of particular modes.

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of the descriptors other than the eight listed were considered unlikely for the specific network involved. In principle, the travel density component of the link description should change over time. For simplicity, in this example, we assumed the density at the mid-point of our analysis--i.e., in about 1985.

*As used here, the terms origin and destination refer to two-way traffic. On a trip one way, the first city in the pair is the origin; going the other way, the same city obviously is the destination.

Table 21

LINK SPECIFICATION FOR THE RAILROAD NETWORK

Number	*Origin Node*	*Destination Node*	*Length (mi)*	*Link Type*	*Circuity Factor*
1	1	2	29	1	1.05
2	1	17	40	3	1.05
3	2	3	25	1	1.05
4	3	4	28	1	1.05
5	4	5	25	1	1.05
6	4	18	27	8	1.00
7	4	19	35	8	1.00
8	5	6	64	1	1.05
9	6	7	35	3	1.05
10	6	8	43	4	1.05
11	6	23	28	4	1.05
12	7	8	42	4	1.05
13	8	9	22	5	1.10
14	9	10	19	6	1.00
15	9	22	57	2	1.10
16	10	11	20	5	1.10
17	11	12	27	2	1.10
18	12	13	33	2	1.10
19	12	21	25	7	1.00
20	12	22	21	7	1.00
21	13	14	19	5	1.10
22	14	15	31	2	1.10
23	15	16	12	4	1.05
24	15	18	21	7	1.00
25	15	20	32	2	1.10
26	16	17	23	5	1.10
27	19	20	14	7	1.00
28	20	21	26	7	1.00
29	20	24	28	7	1.00
30	22	23	18	6	1.00
31	22	24	22	7	1.00

The exact travel distance between nodes i and k is given by

$$y_{ik} = R^* \cos^{-1} [\sin \theta_i \sin \theta_k + \cos \theta_i \cos \theta_k \cos (\phi_i - \phi_k)] \qquad (2)$$

where $R^* = 3963.34$, the radius of the earth in miles, and where θ and ϕ represent the latitude and longitude of the particular node expressed in radians.* In addition, a link circuity function was [redacted]

*The special purpose notations, y and R^*, are used only in Eq. (2).

postulated to account for the different types of terrain over which the railroad has to operate. A link winding through the mountains cannot be expected to take the same time as a link of the same distance on flat ground. The procedure used was to increase the length of a link when the terrain was something other than the best. The link circuity function indicates a factor ≥ 1 to be multiplied by the straight line length of the link. It has a value of 1.00 for level, nonurban terrain, 1.05 for urban terrain, and 1.10 for mountainous terrain. The circuity factors for each link in the network also are identified in Table 21.

These assumptions and functions were used to build an input matrix, $\overline{F} = [F_{ik}]$ of link travel times for the representative network, which could be used as input to a shortest-path algorithm. Solution of that algorithm is the optimal route, and hence minimum travel time, for railroad travel between all pairs of cities in the network. The expression for total trip time, H_{ik}, between origin i and destination k was given by

$$H_{ik} = \sum_{\ell} H_{\ell} + \sum_{n} H_{n}, \tag{3}$$

where H_{ℓ} is the travel time along link ℓ and reflects the link circuity function, and H_{n} is the increment of time added for deceleration and acceleration in node n.* Travel times ranged from a low of 30 minutes from New Town D to New Town E to a high of 343 minutes from New York/Newark to Hagerstown. Table 22 includes the optimal routing and travel time for selected trips within the network.

Additional refinement of the single attribute, single mode case was made by considering the schedule of service that is offered throughout the network. As opposed to the above unrealistic situation where instantaneous service is assumed, two added dimensions were included: (1) initial waiting time at the origin station and (2) additional waiting time if transfers had to be made at interim cities. These added dimensions depend on the timetable or schedule of service avail-

*The symbol H is used in this discussion since travel time in minutes is a physical measure for an attribute.

Table 22

OPTIMAL ROUTINGS AND TRAVEL TIMES OF SELECTED TRIPS, WITH A SINGLE MODE AND INSTANTANEOUS SERVICE

Origin-Destination and Routing	*Travel Time (min.)*
New York/Newark to New Brunswick (1-2)	70
Trenton to Wilmington (3-4-5)	100
New Town D to Pottstown (13-14-15-20-19)	154
New Town F to New Town A (17-16-15-20-24-22-23)	221
New York/Newark to Chambersburg (1-17-16-15-14-13-12-11-10)	323

able in each city for the railroad mode and also the type of service class that was assumed.

Although our objective in writing these routines was to develop ways of handling *worth* information in a network context, using the physical measure travel time did seem like a logical way to get started. This was fortuitous in that it allowed us to briefly introduce scheduling considerations into the analysis. On the other hand, the details of scheduling constitute a difficult subject of its own and pursuing this to any great extent here probably would result in a serious digression. Therefore, the discussion that follows on waiting and transfer time serves only to illustrate the nature of the considerations involved.

First, a schedule time function was postulated. It reflected the maximum wait time for the next train as a function of city type as follows:

City Type	*Maximum Wait Time (min.)*
1	60
2	90
3	135
4	195
5	270
6	360

This means that a train leaves New York every hour, but from a New Town, there is a 6-hour maximum wait. The average wait time was assumed to be one-half of the maximum wait time.

Second, three distinct service classes were identified: express, local, and transfer. An express train does not slow down as it passes through interim cities. The expression for total travel time when a passenger uses express service class was

$$H_{ik}(\text{express}) = \sum_{\ell} H_{\ell} + H_w + (H_i + H_k), \tag{4}$$

where H_{ℓ} is link time for link ℓ, H_w is average wait time in the origin station, and H_i and H_k are accelerate time in i and decelerate time in k, respectively.

Local service class is the same as express except that the train stops in each intermediate city. The expression for total travel time when a passenger uses local service class was

$$H_{ik}(\text{local}) = \sum_{\ell} H_{\ell} + H_w + \sum_{m} H_m, \tag{5}$$

where H_m is the appropriate time for acceleration and/or deceleration in all cities along the route of the total trip. With the exception of H_w, which has been added, Eq. (5) is similar to Eq. (3).

Conversely, transfer service class means that the passenger must transfer to another train at each intermediate node. This is not particularly realistic, but it serves as an upper bound on travel time for the railroad mode.* The analogous expression for calculating travel time for this class became

$$H_{ik}(\text{transfer}) = \sum_{\ell} H_{\ell} + H_w + \sum_{m} H_m + \sum_{r} H_r, \tag{6}$$

where H_r is the average wait time in intermediate node r.

*Some smaller number of transfers might also be assumed, for example, one transfer for each two or three intermediate nodes.

One might argue that express and local service classes should be analyzed as two separate modes and also that wait times should depend not only on city size but also on location in the network. For example, New Brunswick and Trenton are smaller cities but service between these two nodes is relatively frequent because of their location on the chain-of-links between New York and Philadelphia.

For each service class, the shortest-path algorithm was used to solve the network--that is, to determine the optimal routing and travel time for each possible trip. Table 23 includes the results for the same representative trips as in Table 22. The wide range of travel time emphasizes the possible variances resulting from the way in which scheduling is handled. Results also indicate that trip routing is more important than mere distance between origin and destination.

Table 23

OPTIMAL ROUTINGS AND TRAVEL TIMES FOR THREE SERVICE CLASSES, SINGLE MODE

(minutes)

Origin-Destination and Routing	*Service Class*		
	Express	*Local*	*Transfer*
New York/Newark to New Brunswick (1-2)	80	80	80
Trenton to Wilmington (3-4-5)	200	225	270
New Town D to Pottstown (13-14-15-20-19)	291	326	701
New Town F to New Town A (17-16-15-20-24-22-23)	326	396	921
New York/Newark to Chambersburg (1-17-16-15-14-13-12-11-10)	273	333	1383

SINGLE ATTRIBUTE--MIX OF MODES

In order to extend the analysis to more than a single mode, an air network of seven links was added to the railroad network. Air transportation was assumed to average 200 miles per hour. Figure 6 indicates both the rail and air links that comprise a representative mix-of-modes network. Details of the air links are presented as Table 24. The main

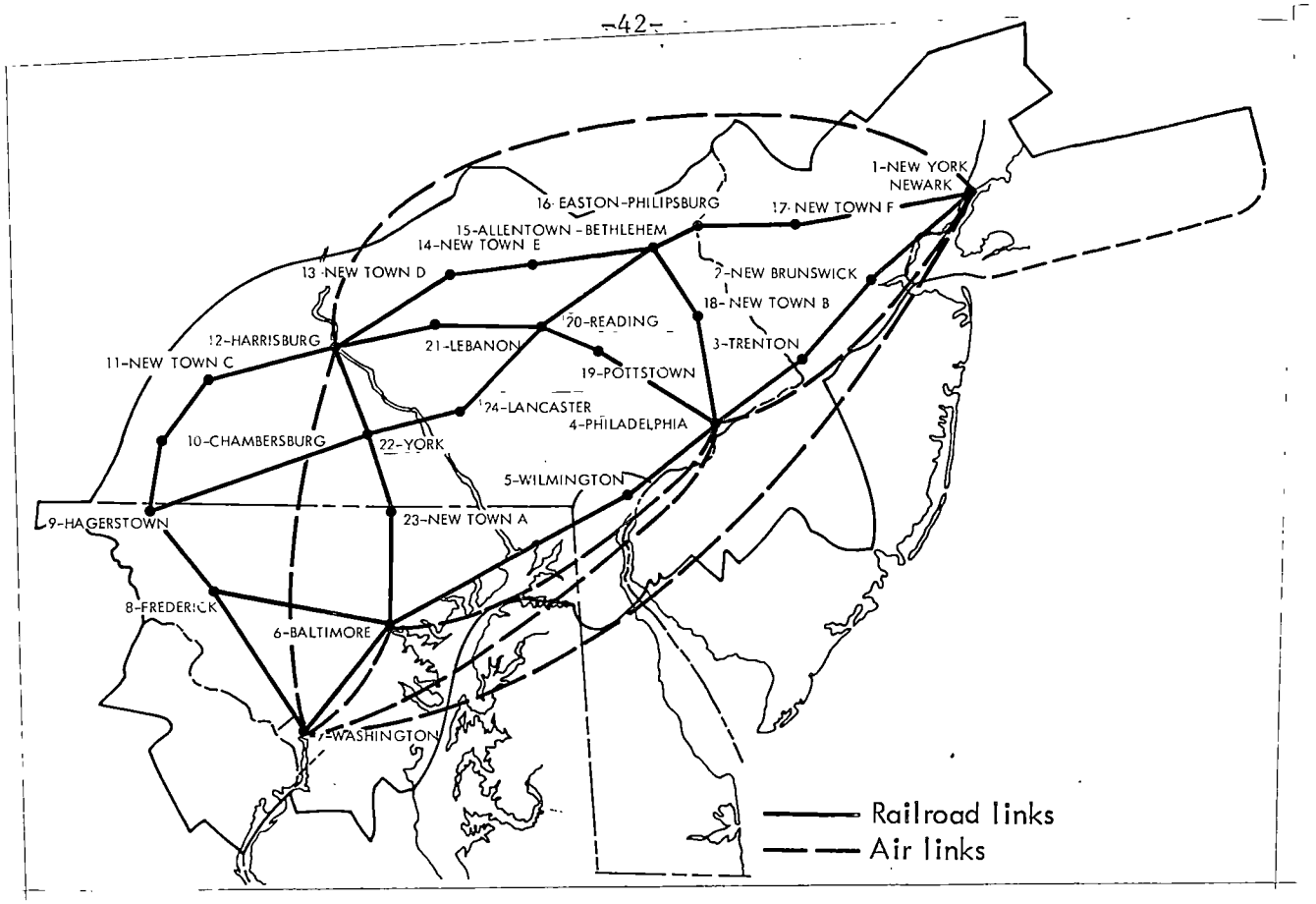


Fig. 6--Illustrative network of railroad and air links

Table 24

LINK SPECIFICATION FOR THE AIR NETWORK

Number	*Origin Node*	*Destination Node*	*Length (mi)*
1	1 (25)	4 (28)	84
2	4 (28)	6 (30)	90
3	6 (30)	7 (31)	35
4	4 (28)	7 (31)	124
5	1 (25)	7 (31)	207
6	1 (25)	12 (36)	156
7	7 (31)	12 (36)	95

NOTE: Air node identifications are shown in parenthesis.

overlap of service with rail is seen to be along the eastern portion of the total network from New York/Newark to Washington.

In order to keep tabs on exactly what mode is used at each point of a total trip, it was necessary to create additional node identifi-

cations. A convenient way of conceptualizing multiple modes is to think in terms of terminals within a city, rather than nodes. In the representative network, railroad terminals were numbered (as before) from 1 to 24, while air terminals were numbered from 25 to 48.* Within node i, the rail terminal was identified as i, and the air terminal was referred to as $(i + 24)$. Only five cities are seen in Fig. 6 to have air terminals (25, 28, 30, 31, and 36), however, so many of the second group of terminal numbers were not actually used. Although the two-mode network is almost as unrealistic as a single-mode network, it can be used to illustrate the importance of modal choice.

If a passenger switches from one mode to another within a given node, then assumptions must be made about the transfer process. For this preliminary exercise, a standardized transfer mode, called "taxicab," was used for all transferring. It was assumed that the taxicab mode averaged 15 miles per hour within all nodes. The distance between air and railroad terminals was postulated to be a function of node size and hence of node type. The following intra-node transfer function was used:

Node Type	*Distance Between Rail and Air Terminals (mi)*
1	15
2	10
3	8
4	6
5	4
6	2

Using these distances and the constant taxicab speed, the transfer time increments were easily calculated. No allowance was made for the time spent waiting for a taxicab--i.e., an assumption of "instant service" was made. Service classes and scheduling also were not included in this subroutine.

*This numbering system emerged in adding on to the computer program for the first routine. In redoing this, it probably would be clearer if a system of nesting were used as suggested in Vol. II--i.e., 1-1 and 1-2 instead of 1 and 25 to represent terminals for different modes within the same city.

The square input matrix $\bar{F} = [F_{ik}]$ for the multi-mode case is larger (potentially 48 × 48) than before (24 × 24) because it is based on terminals rather than nodes. The optimal routing for any origin-destination pair includes the terminals used in the total trip. The terminals identify the modes, links, and transfers necessary to get from origin to destination.

To illustrate the type of solution that results, consider the particular trip from New York/Newark to York. If the trip were made exclusively by railroad, the optimal route would be

1-17-16-15-20-24-22,

which takes the passenger through New Town F, Easton/Phillipsburg, Allentown/Bethlehem, Reading, and Lancaster as intermediate stops. When air service is available, however, the optimal route became

1-25-36-12-22,

which has a somewhat different interpretation. The traveler starts at the railroad terminal (1) in New York/Newark and takes a taxicab to the air terminal (25); he flies to the air terminal at Harrisburg (3) and then takes another taxi to the railroad terminal in that city (12); finally, he takes the train to York (22) which is his destination. Travel time for the latter trip was 151 minutes. Table 25 includes optimal routings and travel times for representative trips in the single attribute, mix of modes case.

Table 25

OPTIMAL ROUTING AND TRAVEL TIME OF SELECTED TRIPS, WITH A MIX OF MODES AND INSTANTANEOUS SERVICE

Origin-Destination and Routing	*Travel Time (min.)*
New York/Newark to Baltimore (1-25-28-30-6)	144
Trenton to Harrisburg (3-4-28-31-36)	134
Trenton to Harrisburg (3-4-19-20-21-12)	129
Washington to Allentown/Bethlehem (7-31-28-4-18-15)	157
New Town F to Baltimore (17-16-15-18-4-28-30)	153

MULTIPLE ATTRIBUTES--INDIVIDUAL MODAL LINKS

The next step in the computer model was to combine numerous user attributes on an individual network link, to give a weighted worth score for the link. Because a link is defined as a mode connecting a pair of cities in the network, a weighted worth score for the link has to do with the reaction of a specific group to travel over a specific mode connecting a specific pair of network terminals. The general approach to the construction of worth functions for this example was discussed briefly in Sec. III and is expanded here. First, we made all individual worth functions *linear* in their physical measure variable and passing through the origin. This is helpful later because it insures that the sum of worth experienced over two successive links with identical mode properties--i.e., average speed, fare per mile, compartment humidity, etc.--is the same as the worth over a single link with the same overall properties as the two links together. The ability to add worth scores in this manner greatly eases selection of the shortest path through the network. Second, we combined worth values for individual lower-level attributes with their respective weights. This simplified the weighting step considerably. Third, basic worth functions were considered the same for all user groups, with group differences being reflected only in differences among the five major attribute weights.

The user worth functions which resulted are shown in an appendix as Table 66. There are two types of attributes. The majority have linear worth functions of a continuous physical measure variable of the form $U = KH$, and we indicate in Table 66 the value H_0 of the physical variable for which $U(H_0) = -1$. The other attributes have either a direct worth estimate or a binary state variable as a physical measure (e.g., is a movie shown or not?). For the first attribute type, the table lists the value of H_0; for the second type it lists the permissible ranges or choices for a worth score, in parentheses.

These worth curves and assessments are so calibrated that a user in the middle income category traveling on business has on the higher-level attributes weights summing to 1. Thus, this particular user's total worth for a trip comes from simply adding the worth scores of--

the individual attributes. The worth curves were calibrated on the Washington to New York trip as described in Sec. III. Note that the curves for time and cost are calculated so that one hour is worth $7.50 and one worth unit is worth $50. The $7.50 value was determined by dividing annual salary for a middle income person by annual working hours. The dollar value of a worth unit was set through an indifference or willingness-to-pay exercise in which the analysts involved estimated what they thought it was worth to avoid experiencing a -1.0 level of disutility on various safety, convenience, and comfort attributes. From these results, an average value was obtained. This step was necessary in order to treat travel cost and travel time consistently with the other user attributes.

The next step was to extend this worth assessment to all user groups. In this case, we assumed the full complement of ten user groups identified in Vol. II. These are listed and numbered in Table 26.

Table 26

PASSENGER USER GROUP

Annual Income	*Trip Purpose*		
	Business	*Pleasure*	*Commutation*
< $4K		4	
≥ $4K < $10K	1	5	8
≥ $10K < $20K	2	6	9
≥ $20K	3	7	10

We assume that the poverty group does not travel intercity except for pleasure; all other combinations are possible.

In a role-playing exercise, we systematically considered the preferences of each of these different groups and assigned a set of weights to the five major attributes indicating their relative importance.* The weights for a given group divided by the weights for group 2 (the reference group) gave the multiplying factors to be used on the major

*As stated in Sec. III, a survey of sample users probably could be designed which would improve upon these weights, if time and resources were available for such an effort.

attribute worth scores to construct a total worth for that group. These factors are given in Table 27.

Table 27

USER GROUP WEIGHTING FACTORS

Higher Level Attribute	*User Group* 1	2	3	4	5	6	7	8	9	10
Time	0.875	1.0	1.25	0.25	0.375	0.5	0.625	0.87	1.0	1.25
Cost	1.75	1.0	0.5	3.5	2.75	2.0	1.5	2.0	1.5	1.0
Safety & Security	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Convenience	0.8	1.0	1.0	0.4	0.8	1.0	1.2	0.6	0.8	0.8
Comfort	0.667	1.0	1.0	0.667	0.667	1.0	1.0	0.667	0.667	0.667

For example, if the worth scores on a given link for group 2 are .3 for time, .2 for cost, .1 for safety, .2 for convenience, and .1 for comfort, the total worth for group 2 is their sum of .9,* while the total worth for group 4 is (.25)(.3) + (3.5)(.2) + (1)(.1) + (.4)(.2) + (.667)(.1) = 1.022.

In order to later extend the worth assessment over a network of links and nodes, one additional point should be made. Many of the attributes are a function of time spent or distance traveled on a given link, and since time can be expressed through our mode characteristics as a function of distance, we can sum over all these attributes to give a total worth per link for that particular mode. Other attributes, however, are constants for a mode, and it would be unfair to add this constant to each link, because the result would then depend on the number of links contained in the total trip. For such cases, the worth score should be added only once for the entire chain of links, assuming the traveler remained on the same mode.

A simple program was constructed to calculate, for a given network and set of mode characteristics, the total worth on each line-haul

*For ease of interpretation, we assume the worth scales have been transferred from negative to positive values by adding +1.0 to each major attribute as discussed in Sec. III.

link for a member of user group 2, with respect to time, cost, safety and security, convenience, and comfort. A sample output of the higher-level worth scores is presented in Table 28. The scores incorporate two important steps. In the table, the lower-level attribute worth scores have been added, and +1.0 also has been added to each subtotal. The origin and destination cities are identified by node numbers as shown in Fig. 4. The modes have identifying numbers as follows:

Number	*Mode*
1	Rail
2	Bus
3	Auto
4	Conventional Aircraft (CTOL)
5	Short Take-off and Landing Aircraft (STOL)
6	Tracked Air Cushion Vehicle (TACV)
7	Dual-Mode Vehicle (DM)
8	Taxi

The network here is the base case network of rail, air, auto, and bus as illustrated in Fig. 4. The links are numbered consecutively, assuming separate links for each mode connecting the origin-destination pairs. The values shown are for user group 2 and summarize link-associated attributes for the line-haul portions of trips.

The same program also calculated the constant worth values to be added for chain of link-associated attributes. For example, the worth scores for user group 2 are presented as Table 29.

Finally, Table 30 is a summary of worth scores for user group 2 including the chain-of-link attributes. The worth scores of Table 29 were added to the appropriate scores in Table 28 as follows: It was estimated by reviewing computer listings of possible trip paths that the typical or average trip over the entire network consisted of three different modes, and each mode was used for two links in the total trip. Since the chain-of-link attribute scores are added only once for each mode, it would be inappropriate to simply add the values in Tables 28 and 29. Instead, we approximated the chain-of-link contribution to total worth by adding one-half the score in Table 29 to the corresponding cell in Table 28. We made this approximation so that all weighted worth

Table 28

LINK WORTH SCORES FOR HIGHER LEVEL USER ATTRIBUTES, USER GROUP 2

Link No.	*Origin Node*	*Dest. Node*	*Mode Number*	*Travel Time*	*Travel Cost*	*Safety & Security*	*Convenience*	*Comfort*
1	1	2	1	0.0647	0.0384	0.0162	0.0	0.0259
2	2	3	1	0.0556	0.0330	0.0139	0.0	0.0222
3	3	4	1	0.0609	0.0361	0.0152	0.0	0.0244
4	4	5	1	0.0547	0.0325	0.0137	0.0	0.0219
5	5	6	1	0.1399	0.0831	0.0350	0.0	0.0560
6	6	7	1	0.0768	0.0456	0.0192	0.0	0.0307
7	4	19	1	0.0720	0.0427	0.0180	0.0	0.0288
8	19	20	1	0.0296	0.0176	0.0074	0.0	0.0118
9	20	21	1	0.0542	0.0322	0.0135	0.0	0.0217
10	21	12	1	0.0526	0.0312	0.0131	0.0	0.0210
11	1	4	4	0.0737	0.1670	0.0214	0.0	0.0697
12	4	6	4	0.0795	0.1803	0.0231	0.0	0.0753
13	1	7	4	0.1828	0.4143	0.0532	0.0	0.1729
14	6	7	4	0.0314	0.0711	0.0091	0.0	0.0297
15	4	7	4	0.1095	0.2482	0.0319	0.0	0.1036
16	7	12	4	0.0837	0.1896	0.0243	0.0	0.0792
17	1	12	4	0.1380	0.3128	0.0402	0.0	0.1306
18	1	2	3	0.0944	0.0252	0.0390	0.0249	0.0779
19	2	3	3	0.0812	0.0216	0.0335	0.0214	0.0670
20	3	4	3	0.0889	0.0237	0.0367	0.0235	0.0734
21	4	5	3	0.0799	0.0213	0.0330	0.0211	0.0659
22	5	6	3	0.2043	0.0545	0.0843	0.0540	0.1686
23	6	7	3	0.1121	0.0299	0.0462	0.0296	0.0925
24	7	8	3	0.1329	0.0355	0.0549	0.0351	0.1097
25	6	8	3	0.1378	0.0368	0.0569	0.0364	0.1138
26	6	23	3	0.0908	0.0242	0.0375	0.0240	0.0750
27	4	19	3	0.1051	0.0280	0.0434	0.0278	0.0867
28	4	18	3	0.0834	0.0222	0.0344	0.0220	0.0688
29	1	17	3	0.1279	0.0341	0.0528	0.0338	0.1056
30	17	16	3	0.0781	0.0208	0.0322	0.0206	0.0644
31	16	15	3	0.0421	0.0112	0.0174	0.0111	0.0347
32	18	15	3	0.0650	0.0173	0.0268	0.0172	0.0537
33	19	20	3	0.0432	0.0115	0.0178	0.0114	0.0356
34	15	20	3	0.1060	0.0283	0.0438	0.0280	0.0875
35	14	15	3	0.1041	0.0277	0.0429	0.0275	0.0859
36	13	14	3	0.0640	0.0171	0.0264	0.0169	0.0529
37	20	21	3	0.0791	0.0211	0.0326	0.0209	0.0653
38	12	13	3	0.1107	0.0295	0.0457	0.0293	0.0914
39	12	21	3	0.0768	0.0205	0.0317	0.0203	0.0634
40	20	24	3	0.0846	0.0226	0.0349	0.0224	0.0698
41	22	24	3	0.0684	0.0182	0.0282	0.0181	0.0565
42	12	22	3	0.0644	0.0172	0.0266	0.0170	0.0532
43	22	23	3	0.0569	0.0152	0.0235	0.0150	0.0469
44	11	12	3	0.0920	0.0245	0.0380	0.0243	0.0759

Table 28 (Cont.)

Link No.	Origin Node	Dest. Node	Mode Number	Travel Time	Travel Cost	Safety & Security	Convenience	Comfort
45	10	11	3	0.0688	0.0184	0.0284	0.0182	0.0568
46	9	10	3	0.0598	0.0160	0.0247	0.0158	0.0494
47	9	22	3	0.1897	0.0506	0.0783	0.0501	0.1566
48	8	9	3	0.0750	0.0200	0.0310	0.0198	0.0619
49	1	2	2	0.0944	0.0239	0.0244	0.0	0.0734
50	2	3	2	0.0812	0.0206	0.0210	0.0	0.0631
51	3	4	2	0.0889	0.0225	0.0230	0.0	0.0691
52	4	5	2	0.0799	0.0202	0.0206	0.0	0.0621
53	5	6	2	0.2043	0.0518	0.0528	0.0	0.1589
54	6	7	2	0.1121	0.0284	0.0290	0.0	0.0872
55	7	8	2	0.1329	0.0337	0.0344	0.0	0.1034
56	6	8	2	0.1378	0.0349	0.0356	0.0	0.1072
57	6	23	2	0.0908	0.0230	0.0235	0.0	0.0706
58	4	19	2	0.1051	0.0266	0.0272	0.0	0.0817
59	4	18	2	0.0834	0.0211	0.0215	0.0	0.0648
60	1	17	2	0.1279	0.0324	0.0331	0.0	0.0995
61	17	16	2	0.0781	0.0198	0.0202	0.0	0.0607
62	16	15	2	0.0421	0.0107	0.0109	0.0	0.0327
63	18	15	2	0.0650	0.0165	0.0168	0.0	0.0506
64	19	20	2	0.0432	0.0109	0.0112	0.0	0.0336
65	15	20	2	0.1060	0.0269	0.0274	0.0	0.0825
66	14	15	2	0.1041	0.0264	0.0269	0.0	0.0809
67	13	14	2	0.0640	0.0162	0.0166	0.0	0.0498
68	20	21	2	0.0791	0.0200	0.0204	0.0	0.0615
69	12	13	2	0.1107	0.0280	0.0286	0.0	0.0861
70	12	21	2	0.0768	0.0195	0.0198	0.0	0.0597
71	20	24	2	0.0846	0.0214	0.0219	0.0	0.0658
72	12	22	2	0.0644	0.0163	0.0167	0.0	0.0501
73	22	23	2	0.0569	0.0144	0.0147	0.0	0.0442
74	22	24	2	0.0684	0.0173	0.0177	0.0	0.0532
75	11	12	2	0.0920	0.0233	0.0238	0.0	0.0715
76	10	11	2	0.0688	0.0174	0.0178	0.0	0.0535
77	9	10	2	0.0598	0.0152	0.0155	0.0	0.0465
78	9	22	2	0.1897	0.0480	0.0490	0.0	0.1475
79	8	9	2	0.0750	0.0190	0.0194	0.0	0.0583

values can be associated with individual links. Thus, we now have estimates of the worth of single trips over each modal line-haul link by an individual in user group 2. This data, presented in Table 30, will be used later in computing link and network benefit. They are not used in calculating either the optimal path or link flows through the network for a given group and time period.

Table 29

CONSTANT WORTH INCREMENTS FOR A CHAIN OF LINKS

Mode No.	Time	Cost	Safety & Security	Convenience	Comfort
1	.0000	.0000	.0439	.3356	.0270
2	.0000	.0000	.0439	.2511	.0560
3	.0000	.0000	.0000	.2150	-.1320
4	.0000	.0000	.0439	.3720	.0225
5	.0000	.0000	.0439	.3720	.1025
6	.0000	.0000	.0439	.3053	-.0920
7	.0000	.0000	.0000	.0250	-.0720
8	.0000	.0000	.0000	.1250	.1010

Table 30

LINK WORTH SCORES FOR HIGHER LEVEL USER ATTRIBUTES, USER GROUP 2, INCLUDING CHAIN-OF-LINK ATTRIBUTES

Link No.	Origin Node	Dest. Node	Mode Number	Travel Time	Travel Cost	Safety & Security	Convenience	Comfort
1	1	2	1	0.0647	0.0384	0.0381	0.1678	0.0394
2	2	3	1	0.0556	0.0330	0.0358	0.1678	0.0357
3	3	4	1	0.0609	0.0361	0.0372	0.1678	0.0379
4	4	5	1	0.0547	0.0325	0.0356	0.1678	0.0354
5	5	6	1	0.1399	0.0831	0.0569	0.1678	0.0695
6	6	7	1	0.0768	0.0456	0.0411	0.1678	0.0442
7	4	19	1	0.0720	0.0427	0.0399	0.1678	0.0423
8	19	20	1	0.0296	0.0176	0.0293	0.1678	0.0253
9	20	21	1	0.0542	0.0322	0.0355	0.1678	0.0352
10	21	12	1	0.0526	0.0312	0.0351	0.1678	0.0345
11	1	4	4	0.0737	0.1670	0.0434	0.1860	0.0810
12	4	6	4	0.0795	0.1803	0.0451	0.1860	0.0865
13	1	7	4	0.1828	0.4143	0.0751	0.1860	0.1842
14	6	7	4	0.0314	0.0711	0.0311	0.1860	0.0409
15	4	7	4	0.1095	0.2482	0.0538	0.1860	0.1148
16	7	12	4	0.0837	0.1896	0.0463	0.1860	0.0904
17	1	12	4	0.1380	0.3128	0.0621	0.1860	0.1418
18	1	2	3	0.0944	0.0252	0.0390	0.1324	0.0119
19	2	3	3	0.0812	0.0216	0.0335	0.1289	0.0010
20	3	4	3	0.0889	0.0237	0.0367	0.1310	0.0074
21	4	5	3	0.0799	0.0213	0.0330	0.1286	-0.0001
22	5	6	3	0.2043	0.0545	0.0843	0.1615	0.1026
23	6	7	3	0.1121	0.0299	0.0462	0.1371	0.0265
24	7	8	3	0.1329	0.0355	0.0549	0.1426	0.0437
25	6	8	3	0.1378	0.0368	0.0569	0.1439	0.0478
26	6	23	3	0.0908	0.0242	0.0375	0.1315	0.0090
27	4	19	3	0.1051	0.0280	0.0434	0.1353	0.0207
28	4	18	3	0.0834	0.0222	0.0344	0.1295	0.0028
29	1	17	3	0.1279	0.0341	0.0528	0.1413	0.0396
30	17	16	3	0.0781	0.0208	0.0322	0.1281	-0.0016

Table 30--continued

Link No.	Origin Node	Dest. Node	Mode Number	Travel Time	Travel Cost	Safety & Security	Convenience	Comfort
31	16	15	3	0.0421	0.0112	0.0174	0.1186	-0.0313
32	18	15	3	0.0650	0.0173	0.0268	0.1247	-0.0123
33	19	20	3	0.0432	0.0115	0.0178	0.1189	-0.0304
34	15	20	3	0.1060	0.0283	0.0438	0.1355	0.0215
35	14	15	3	0.1041	0.0277	0.0429	0.1350	0.0199
36	13	14	3	0.0640	0.0171	0.0264	0.1244	-0.0131
37	20	21	3	0.0791	0.0211	0.0326	0.1284	-0.0007
38	12	13	3	0.1107	0.0295	0.0457	0.1368	0.0254
39	12	21	3	0.0768	0.0205	0.0317	0.1278	-0.0026
40	20	24	3	0.0846	0.0226	0.0349	0.1299	0.0038
41	22	24	3	0.0684	0.0182	0.0282	0.1256	-0.0095
42	12	22	3	0.0644	0.0172	0.0266	0.1245	-0.0128
43	22	23	3	0.0569	0.0152	0.0235	0.1225	-0.0191
44	11	12	3	0.0920	0.0245	0.0380	0.1318	0.0099
45	10	11	3	0.0688	0.0184	0.0284	0.1257	-0.0092
46	9	10	3	0.0598	0.0160	0.0247	0.1233	-0.0166
47	9	22	3	0.1897	0.0506	0.0783	0.1576	0.0906
48	8	9	3	0.0750	0.0200	0.0310	0.1273	-0.0041
49	1	2	2	0.0944	0.0239	0.0464	0.1255	0.1014
50	2	3	2	0.0812	0.0206	0.0429	0.1255	0.0911
51	3	4	2	0.0889	0.0225	0.0449	0.1255	0.0971
52	4	5	2	0.0799	0.0202	0.0426	0.1255	0.0901
53	5	6	2	0.2043	0.0518	0.0748	0.1255	0.1869
54	6	7	2	0.1121	0.0284	0.0509	0.1255	0.1152
55	7	8	2	0.1329	0.0337	0.0563	0.1255	0.1314
56	6	8	2	0.1378	0.0349	0.0576	0.1255	0.1352
57	6	23	2	0.0908	0.0230	0.0454	0.1255	0.0986
58	4	19	2	0.1051	0.0266	0.0491	0.1255	0.1097
59	4	18	2	0.0834	0.0211	0.0435	0.1255	0.0928
60	1	17	2	0.1279	0.0324	0.0550	0.1255	0.1275
61	17	16	2	0.0781	0.0198	0.0421	0.1255	0.0887
62	16	15	2	0.0421	0.0107	0.0328	0.1255	0.0607
63	18	15	2	0.0650	0.0165	0.0388	0.1255	0.0786
64	19	20	2	0.0432	0.0109	0.0331	0.1255	0.0616
65	15	20	2	0.1060	0.0269	0.0494	0.1255	0.1105
66	14	15	2	0.1041	0.0264	0.0488	0.1255	0.1089
67	13	14	2	0.0640	0.0162	0.0385	0.1255	0.0778
68	20	21	2	0.0791	0.0200	0.0424	0.1255	0.0895
69	12	13	2	0.1107	0.0280	0.0506	0.1255	0.1141
70	12	21	2	0.0768	0.0195	0.0418	0.1255	0.0877
71	20	24	2	0.0846	0.0214	0.0438	0.1255	0.0938
72	12	22	2	0.0644	0.0163	0.0386	0.1255	0.0781
73	22	23	2	0.0569	0.0144	0.0367	0.1255	0.0722
74	22	24	2	0.0684	0.0173	0.0396	0.1255	0.0812
75	11	12	2	0.0920	0.0233	0.0457	0.1255	0.0995
76	10	11	2	0.0688	0.0174	0.0397	0.1255	0.0815
77	9	10	2	0.0598	0.0152	0.0374	0.1255	0.0745
78	9	22	2	0.1897	0.0480	0.0710	0.1255	0.1755
79	8	9	2	0.0750	0.0190	0.0413	0.1255	0.0863

ACCESS-EGRESS AND TRANSFER ASSESSMENT

The access, egress and transfer portions of total trips are handled by adding more nodes and links to the network. Each city may be divided into nine zones. This is accomplished by dividing each of the two outer rings of the three ring city model, described earlier, into four equal sectors. Then terminals are assigned for each of the seven line-haul modes we have identified. Terminals for different modes are assumed to each be located in a separate zone. This assumption is arbitrary but does seem to suggest a balance of service throughout our generalized representation of a city, as shown in Fig. 7.

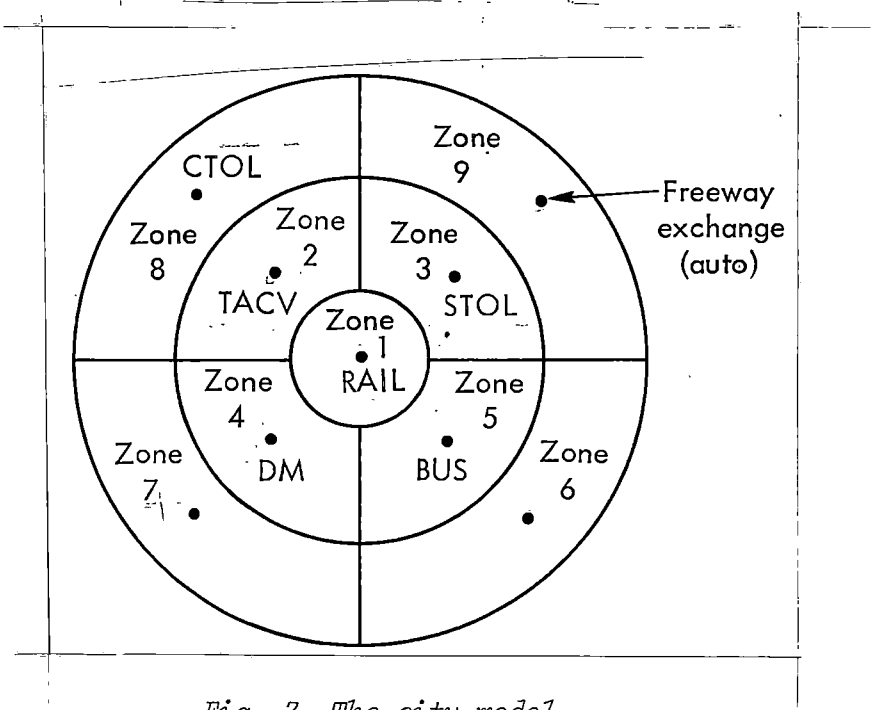


Fig. 7--The city model

The ring radii for each of the six city sizes were given in Table 3. Distances between zone pairs are computed as straight-line distances between the centroids of the zones. These distances for a city of type 6 are given in Table 31. To obtain the distances for a city of another type, we need only multiply by the appropriate factor inferred from the ring radii of Table 3.

An access or egress trip segment is represented as a trip between an origin or destination zone and the terminal of the chosen mode, which

Table 31

INTERCITY ZONE DISTANCES WITHIN CITY SIZE 6

(in miles)

Origin Zone	*Destination Zone*	*Inter-Zone Distance*	*Origin Zone*	*Destination Zone*	*Inter-Zone Distance*
2	1	2.00	7	4	2.50
3	1	2.00	7	5	4.92
3	2	2.83	7	6	6.36
4	1	2.00	8	1	4.50
4	2	2.83	8	2	2.50
4	3	4.00	8	3	4.92
5	1	2.00	8	4	4.92
5	2	4.00	8	5	6.50
5	3	2.83	8	6	9.00
5	4	2.83	8	7	6.36
6	1	4.50	9	1	4.50
6	2	6.50	9	2	4.92
6	3	4.92	9	3	2.50
6	4	4.92	9	4	6.50
6	5	2.50	9	5	4.92
7	1	4.50	9	6	6.36
7	2	4.92	9	7	9.00
7	3	6.50	9	8	6.36

may lie in the same zone or in another zone. A mode transfer is a trip segment within a city between one mode terminal (in one zone) and another mode terminal (in another zone). For simplicity, we have assumed that all access, egress, and transfer segments are taken on the taxi mode, which has characteristics identical to the automobile except for a higher fare and a speed typical of city traffic instead of freeway traffic.* Constant and per-mile worths are computed in the same way as for the line-haul modes, and the summarized results for user group 2 are graphed in Fig. 8. These estimating relationships can then be applied to the access, egress, or transfer links for a total trip.

MULTIPLE ATTRIBUTES: MIX OF MODES

To illustrate how the link worth scores can be used to determine the optimal path through the network, we return to the simplified network

*No provision has been made for handling transfers within mode, for example, from one airplane to another.

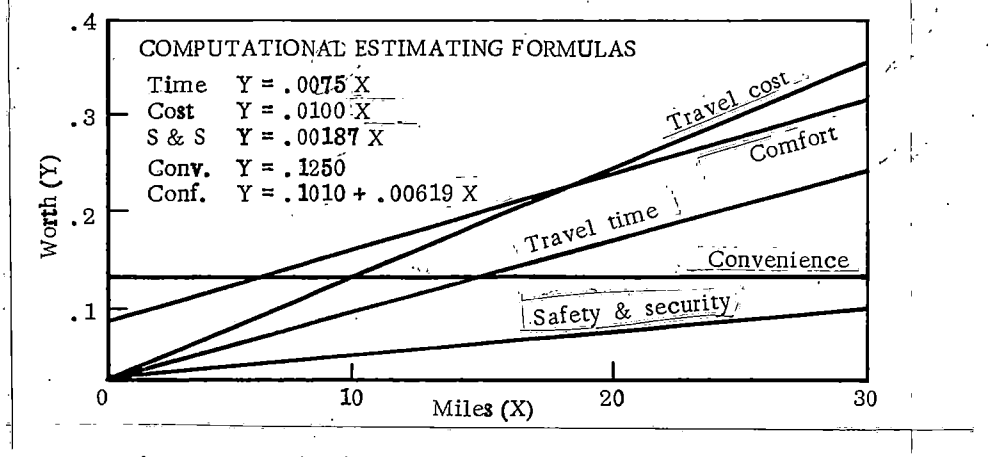


Fig. 8--Taxi characteristics for user group 2

of Fig. 6 consisting of 31 railroad links and 7 air links. The basic idea is to build a suitable matrix $\overline{F}$ to which a shortest-path algorithm can be applied. The matrix is square and of size 48, since the maximum number of terminals is $n = 24$ nodes times $m = 2$ nodes. Although we do not include the access and egress links in this illustration, it is not a difficult matter to extend the illustration to incorporate them.*

The procedure for constructing the appropriate input matrix for a particular user group is as follows. First, the user attributes for each link (e.g., Table 28†) are multiplied by the appropriate weights (Table 27), added to give a weighted worth value for each intercity travel link in the network, and the results entered in the appropriate cells of the input matrix. Second, the estimating formulas (Fig. 8) are used to calculate attribute measures corresponding to each transfer link. These, in turn, are weighted (Table 27) and added giving a weighted worth value for each transfer link. A transfer link exists in every city having more than a single terminal. Third, the chain-of-link attribute worth scores (Table 29) are properly weighted (Table 27) and summed, and then added to the appropriate cells for all transfer

*A method is suggested in the network representation discussion in Sec. VI of Vol. II.

†Actually, only similar to Table 28, except that the original negative worth values underlying the table should be multiplied by -1.0 to obtain positive numbers instead of being transformed by adding +1.0. The reasoning behind this is included in the discussion of optimal trip routing in Sec. VI of Vol. II. Ref. 11.

links.* That is, the chain-of-link attributes are added in only when the traveler switches from one travel mode to another. Finally, all cells in the input matrix that have not received weighted worth scores in these steps are assigned prohibitively large values.

By proceeding in this manner, the resulting input matrix has a weighted worth score in each cell corresponding to an intercity or transfer link, and prohibitively large values elsewhere. The weighted worth score represents a measure of disutility or impedance for each link. The shortest-path algorithm finds the particular route, for each origin-destination combination, that minimizes the total trip impedance. The important point is that optimal routing is based on the total package of user attributes, and the perceptions of a given group to those attributes, rather than just on travel time as was used earlier in this section.

To illustrate, we consider the trip from the railroad terminal in New York/Newark (1) to the railroad terminal in Chambersburg (10). The optimal routing for the trip is 1-25-36-12-11-10 which is interpreted as first flying from New York/Newark to Harrisburg and then taking a railroad to Chambersburg. In this simple two-mode model, all ten user groups identified in Table 26 choose the same sequence of travel services. The following list presents the total weighted worth score for individuals in each group, a series of values ranging from 2.944 (group 3) to 5.111 (group 4):

User Group	*Minimum Total Weighted Worth*
1	3.793
2	3.376
3	2.944
4	5.111
5	4.656
6	4.238
7	3.903
8	3.910
9	3.578
10	3.146

*Earlier, to determine link worth estimates, we made an assumption concerning the average number of transfers per trip and this was used to assign chain-of-link attributes to individuals. The shortest-path

We shall see presently that such values are a useful input to demand forecasting.

LINK FLOWS

The next to final step in the computerized analysis is to determine the link flows, which are the number of times each link is used during some specified period. It may be thought of as a transformation of total travel demand to particular links within the network. Two illustrations of this step are presented. The first is based on our simplified rail-air network, without access and egress, a single user group, and with demand independent of trip parameters. The second more complicated illustration is based on total access-line haul-egress trips from origin zone to destination zone, the full spectrum of transportation modes, two user groups, and demand dependent on trip parameters.

For the first case, trip demand between cities was assumed to be

$$D(i, k) = KP(i)P(k), \tag{7}$$

where $P(i)$ and $P(k)$ are the forecasted populations of origin and destination, respectively, and K is a calibration constant. For simplicity, we also assumed that demand $D(i, k)$ is further divided evenly between all terminal combinations within the origin and destination cities. When the optimal routing for each terminal combination in the network is calculated, the use of each link in the optimal path is multiplied by the number of travelers assumed to use the path. We assume, therefore, that each traveler in the user group selects the optimal routing which is based on the total package of user attributes and their corresponding worth scores.

Table 32 includes link flows for selected links in the rail-air network of Fig. 6. Total demand was assumed the same for each group,

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algorithm determines preferred routes and, hence, also identifies transfers. If desired, this information on transfers which is generated by the algorithm can be iterated in the routine to refine the resulting worth values.

Table 32

LINK FLOWS BY LINK AND USER GROUP FOR A TWO-MODE NETWORK

User Group	Link Defined by Terminal Numbers						
	1 and 2	*6 and 7*	*11 and 12*	*4 and 18*	*22 and 24*	*25 and 28*	*31 and 36*
1	14,104	29,500	22,007	53,783	48,719	250,348	29,295
2	64,473	46,377	21,880	54,258	36,375	196,349	26,406
3	64,473	46,377	21,880	54,258	36,375	196,349	26,406
4	14,104	32,277	24,292	49,716	45,918	257,351	41,462
5	14,104	29,500	22,027	53,783	48,719	250,348	29,295
6	64,932	29,500	22,027	53,783	48,719	199,519	29,295
7	64,473	46,377	21,880	54,258	36,375	196,349	26,406
8	14,104	29,500	22,027	53,783	48,719	250,348	29,295
9	64,932	27,003	22,027	53,783	48,719	199,519	29,295
10	64,473	43,636	22,027	54,258	36,375	199,519	29,295

hence summing the link flows across user groups is not a relevant calculation. Instead, the data in Table 32 are useful in checking the sensitivity of the respective user group weights when analyzed in a network context. We see that several numbers repeat within a given column, which defines a particular link in the network. This means that the optimal routings are the same for each group. As one might expect, duplication, and hence group insensitivity, is more pronounced for certain links where air service does not compete directly with rail service. For example, link flows for the rail link from New Town C (11) to Harrisburg (12) repeat across groups more so than for the air link from New York/Newark (25) to Philadelphia (28). A full distribution of link flows across the entire network reveals that the air links tend to be used where possible--that is, they contribute less disutility to the worth measurement for total trips.

For the second case, a total trip originates at a particular zone in one city and terminates at a given zone in another city. All eight modes are allowed. This particular application places severe storage requirements on the computer system being used. Since there were 24 cities and 9 zones in each city, there were $24 \times 9 = 216$ network nodes and $(216)^2 = 46{,}656$ locations required for storage of the array of link worths. Storing a table to record the optimal paths as computed increases core storage requirements. On an IBM 360 model 91 computer,

the program required approximately 372K bytes of core for primary storage in addition to program storage. Thus, a large core availability is necessary for a problem of this size.

After computing the shortest paths, the next step is to compute demand information along each of these paths between nodes in different cities (corresponding to intercity trips). We divide the groups into business (g = 1, 2, 3) and pleasure (g = 4, 5, 6, 7), ignoring the commuters in this illustration. We assume that a pleasure trip starts at the traveler's home and ends at another's home, while a business trip starts at one's home and ends at another's business. Hence, the trip origins in each case are distributed, for a given group, proportionally to the residential dispersion of the group among the city zones. However, in case of a business trip, we assume the trip destinations are distributed proportionally to the employment dispersion among the city zones. We also assume that the destinations are distributed independently of the traveler's income, that is, dependent only on whether his purpose is business or pleasure. Return trips are assumed to be symmetric.

To be more specific, let n' = city type, with the assumed average populations $P(n')$ as given in Table 6. Let z = city zone and g = group. Then we define the origin sector population as

$$P_i(n', z, g) = P(n')\beta(z, g), \tag{8}$$

and the destination sector population as

$$P_k(n', z, g) = P(n')\gamma(z, g), \tag{9}$$

where $\beta(z, g)$ is a residential percentage for zone z and group g and $\gamma(z, g)$ is a destination percentage. Values of $\beta(z, g)$ and $\gamma(z, g)$ are included in Tables 33 and 34, respectively, as derived from the distribution by income and ring in Table 5. Following Lansdowne [3], the demand for trips in this second case is

$$D(i, k) = K(g)P_i(n', z, g)P_k(n', z, g)F^{*E}, \tag{10}$$

Table 33

RESIDENTIAL DISTRIBUTION PER ZONE $\beta(z, g)$

(fractions)

		User Group, g						
		Business				*Pleasure*		
City Ring	*City Zone z*	*Lower 1*	*Middle 2*	*Upper 3*	*Poverty 4*	*Lower 5*	*Middle 6*	*Upper 7*
1	1	.20	.08	.02	.065	.20	.08	.02
2	2-5	.025	.048	.01	.004	.025	.048	.01
3	6-9	.05	.012	.005	.005	.05	.012	.005

Table 34

DESTINATIONS-FRACTION PER ZONE $\gamma(z, g)$

		User Group, g	
City Ring	*City Zone, z*	*Employment 1, 2, & 3*	*Residential 4, 5, 6, & 7*
1	1	.537	.365
2	2-5	.094	.087
3	6-9	.022	.072

where F^* is the total weighted worth for the optimal route between i and k, E is a negative exponent showing the elasticity of demand with respect to worth, and $K(g)$ is an appropriate calibration constant for group g.

We further assumed a value of $E = -1.0$, and calibrated the formula using an estimate of one million annual round trips by people of group 2 between New York and Washington. Using that number for $K(2)$, we assumed that a user's propensity to travel is proportional to his income $Y(g)$ raised to a power,* as follows:

$$K(g) \propto [Y(g)]^{1.28}, \tag{11}$$

where the particular exponent comes from a Mathematica report [11]. Assuming the annual incomes as $3000 for the poverty group, $7000 for

*The symbol Y is used only in this equation.

the lower income group, $15,000 for the middle income group, and $30,000 for the upper income group, we get calibration constants as follows:

User Group	*Calibration Constant*
1	$.45 \times 10^{-7}$
2	1.2×10^{-7}
3	2.9×10^{-7}
4	$.15 \times 10^{-7}$
5	$.45 \times 10^{-7}$
6	1.2×10^{-7}
7	2.9×10^{-7}

The computer program transformed or assigned the zone pair demands to the line-haul links in each optimal path between zone pairs and summed* in order to get link flows. Using this procedure, link flows can be determined. Unlike the first case, the results are based on demand forecasts related to the optimal routing. Table 35, for user groups 2 and 4, presents the resulting link flows for this more sophisticated network and choice of modes.

Table 35

LINK FLOWS FOR USER GROUPS 2 AND 4, BASE MIX, 1970

Link No.	*Origin Node*	*Destination Node*	*Mode Number*	*Link Flow Group 2*	*Link Flow Group 4*
1	1	2	1	757,175	39,692
2	2	3	1	1,306,984	55,230
3	3	4	1	994,368	45,230
4	4	5	1	496,616	21,948
5	5	6	1	436,079	20,945
6	6	7	1	152,266	9,461
7	4	19	1	249,978	10,113
8	19	20	1	233,062	9,463
9	20	21	1	126,387	3,903
10	21	12	1	79,022	2,594
11	1	4	4	106,678	681
12	4	6	4	62,893	247
13	1	7	4	39,851	24

*In order to compute demands efficiently, another large array (of 46K words) is required. However, by using two byte integer arithmetic, the optimal path table and travel demand can be stored together without increasing total storage requirements. For computer systems without two-byte integer arithmetic, storage requirements would have to be increased accordingly.

Table 35--continued

Link No.	Origin Node	Destination Node	Mode Number	Link Flow Group 2	Link Flow Group 4
14	6	7	4	2,681	56
15	4	7	4	16,226	65
16	7	12	4	4,053	19
17	1	12	4	15,793	30
18	1	2	3	21,786	4,351
19	2	3	3	24,223	4,112
20	3	4	3	18,981	4,217
21	4	5	3	8,736	2,311
22	5	6	3	7,178	1,597
23	6	7	3	17,653	1,421
24	7	8	3	5,560	361
25	6	8	3	20,394	831
26	6	23	3	37,922	3,033
27	4	19	3	29,221	1,594
28	4	18	3	34,929	2,263
29	1	17	3	77,126	4,358
30	17	16	3	77,695	4,786
31	16	15	3	74,530	4,496
32	18	15	3	33,461	2,173
33	19	20	3	29,312	1,620
34	15	20	3	34,227	2,012
35	14	15	3	5,354	328
36	13	14	3	2,636	145
37	20	21	3	7,520	652
38	12	13	3	3,484	127
39	12	21	3	7,030	596
40	20	24	3	73,397	4,759
41	22	24	3	38,409	3,278
42	12	22	3	34,795	1,339
43	22	23	3	36,992	3,142
44	11	12	3	16,273	584
45	10	11	3	12,833	410
46	9	10	3	5,318	310
47	9	22	3	4,038	213
48	8	9	3	13,329	670
49	1	2	2	100,489	3,312
50	2	3	2	145,036	8,240
51	3	4	2	115,326	5,199
52	4	5	2	65,190	3,843
53	5	6	2	59,627	3,356
54	6	7	2	33,387	2,001
55	7	8	2	1,636	35
56	6	8	2	5,395	283
57	6	23	2	23,591	807
58	4	19	2	17,782	584
59	4	18	2	10,694	240
60	1	17	2	63,568	4,531
61	17	16	2	79,486	5,345
62	16	15	2	75,399	5,206

Table 35--continued

Link No.	*Origin Node*	*Destination Node*	*Mode Number*	*Link Flow Group 2*	*Link Flow Group 4*
63	18	15	2	11,167	277
64	19	20	2	21,259	937
65	15	20	2	62,235	4,777
66	14	15	2	2,324	156
67	13	14	2	1,204	130
68	20	21	2	17,533	1,402
69	12	13	2	799	26
70	12	21	2	13,174	949
71	20	24	2	63,487	3,793
72	12	22	2	7,485	193
73	22	23	2	26,712	1,013
74	22	24	2	49,408	2,737
75	11	12	2	7,150	560
76	10	11	2	5,320	462
77	9	10	2	1,706	42
78	9	22	2	6,189	490
79	8	9	2	4,202	106

LINK AND NETWORK BENEFIT

In order to complete the example and derive an estimate of benefit for user group 2, the link flows of Table 35 must be combined with the link worth information in Table 30. The first step is to aggregate worth scores across the five higher-level attributes for each link. Recalling that the relative weights for the higher-level attributes are unity for user group 2 (Table 27), the five worth scores are simply added for each link.*

The second step is to weight each link worth value by its corresponding link flow, and add over all links in the network as follows:

$$B^{U}_{gt'} = \sum_{\ell=1}^{L} F^{*'}_{gt'}(\ell) \times I_{gt'}(\ell), \qquad (12)$$

where $B^{U}_{gt'}(\ell)$ is the aggregate benefit for link ℓ and $I_{gt'}(\ell)$ is the link flow. Table 36 illustrates this calculation and shows how each

*For other user groups, the five higher-level-attribute worth scores would have to be adjusted using the weighting factors in Table 27 before adding to derive total link worth.

Table 36

CALCULATION OF DEMAND-WEIGHTED BENEFIT

USER GROUP 2, 1970

Link No.	Link Worth	Link Flow	Link Benefit	Link No.	Link Worth	Link Flow	Link Benefit
1	0.6517	757175	493436	41	0.7690	38409	29538
2	0.6720	1306984	878342	42	0.7801	34795	27144
3	0.6602	994368	656450	43	0.8010	36992	29631
4	0.6740	496616	334740	44	0.7038	16273	11453
5	0.4828	436079	210545	45	0.7679	12833	9854
6	0.6246	152266	95098	46	0.7929	5318	4216
7	0.6353	249978	158809	47	0.4333	4038	1749
8	0.7304	233062	170226	48	0.7508	13329	10007
9	0.6752	126387	85336	49	0.6084	100489	61133
10	0.6788	79022	53637	50	0.6387	145036	92632
11	0.4489	106678	47886	51	0.6210	115326	71617
12	0.4226	62893	26578	52	0.6417	65190	41830
13	0.0424	39851	1690	53	0.3567	59627	21272
14	0.6394	2681	1714	54	0.5679	33387	18961
15	0.2877	16226	4668	55	0.5201	1636	851
16	0.4040	4053	1637	56	0.5089	5395	2745
17	0.1592	15793	2513	57	0.6166	23591	14546
18	0.6971	21786	15186	58	0.5839	17782	10383
19	0.7338	24223	17774	59	0.6336	10694	6775
20	0.7124	18981	13522	60	0.5316	63568	33795
21	0.7374	8736	6442	61	0.6458	79486	51330
22	0.3928	7178	2819	62	0.7281	75399	54900
23	0.6482	17653	11442	63	0.6757	11167	7545
24	0.5904	5560	3282	64	0.7256	21259	15426
25	0.5768	20394	11763	65	0.5817	62235	36203
26	0.7071	37922	26813	66	0.5863	2324	1362
27	0.6676	29221	19506	67	0.6779	1204	816
28	0.7276	34929	25416	68	0.6434	17533	11280
29	0.6043	77126	46607	69	0.5710	799	456
30	0.7424	77695	57677	70	0.6487	13174	8546
31	0.8420	74530	62751	71	0.6308	63487	40048
32	0.7785	33461	26049	72	0.6770	7485	5067
33	0.8389	29312	24590	73	0.6943	26712	18545
34	0.6649	34227	22757	74	0.6678	49408	32997
35	0.6704	5354	3589	75	0.6139	7150	4389
36	0.7812	2636	2059	76	0.6669	5320	3548
37	0.7395	7520	5561	77	0.6875	1706	1173
38	0.6519	3484	2271	78	0.3903	6189	2415
39	0.7459	7030	5244	79	0.6527	4202	2743
40	0.7243	73397	53158	Total			4488404

link of the network contributes to the total demand-weighted benefit for user group 2 during year 1970.

SUMMARY

The detailed computerized analysis of user benefit has been carried through to a prediction of link flows in the network and an aggregate measure of user benefit over the entire network. The analysis has been illustrated for a simple air-rail network and then more completely for the full network of intercity and transfer modes, including the important access-egress segments of the total trip. For each link, the demand for travel was multiplied by an apportioned measure of worth for that link. In this way, it was possible to see how each link, and hence each travel mode, contributed to the total measure of user benefit for all links and modes.

V. DETAILED ANALYSES OF SELECTED SOCIETAL ATTRIBUTES*

INTRODUCTION

This section discusses some detailed work on the measurement of individual societal attributes. First, we include a worth evaluation of air pollution, going through the various steps of spatial partitioning and finding the number of people affected at various intensity levels. Calculations are carried to the point of estimating impacts region-wide.

Next, we present an evaluation of noise effects showing that a range of alternative methods incorporating differing degrees of quantification can be used. This illustration emphasizes quantification in terms of physical measures as well as worth units.

We also include a brief discussion on structuring of the housing attribute. Our purpose in including this is two-fold. We wanted to illustrate the early stages in an exploratory effort searching for appropriate measures for an attribute. In addition, it is important to start developing mechanisms for tracing second-order effects, for example, of transportation on housing via the intermediary step of changing disposable personal income or land use patterns.

AN EVALUATION OF AIR POLLUTION

There are two main sources of air pollution resulting directly from transportation: automotive vehicles and airplanes. Stationary industrial pollution sources also may be relocated as a result of transportation changes, but we shall not consider these here.

We first evaluate the air pollution in a single metropolitan area and then aggregate over the whole region. In both cases, we show the effect of changing the intercity mix of modes, described in Sec. II, from the base mix to the mix with TACV/STOL additions, and to the mix

*Further discussion of the methodology illustrated in this section is found in Sec. VII of Vol. II. In addition, several of the various measurement methods described in Sec. V of Vol. II are illustrated in this section in terms of the attribute *noise*.

with Dual-Mode additions. The evaluation year is 2000, after all planned additions for the new systems have been implemented.*

Let us start by analyzing the pollution impact on a city of size type 3--i.e., with a population of between one- and four-million people. We assume that automobile-induced air pollution is generally worst in the center of the city and milder in the suburbs and outlying areas. Also, it is heaviest during working days, since the vehicle-miles driven by workers and shoppers probably are greater on working days than at other times. We next make the simplifying assumption that one suffers automotive air pollution only at one's location during the working day.

Assume for the base mix of modes that those in city ring 1 suffer a -.2 worth level, those in ring 2 suffer a -.1 worth level, and those in ring 3 do not experience any significant discomfort. In this exercise we also assume that these values reflect the impact of all automotive pollution generated by both intercity and intracity traffic. To establish subjective estimates, whether in worth points or in dollars per year, two pieces of information are needed: a function relating subjective worth to the concentration of various pollutants and a prediction of these concentrations. The first requires an empirical study; the second, some technological forecasting and a "scenario" of future urban conditions.

Using Table 4 and assuming .378 of the people are employed, we can find the number of people in the first and second rings during a working day. Assuming an average population of 2.5 million we can calculate the information in Table 37.

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*A note of caution is raised concerning projection of future impact of the automobile as a polluter. There is evidence to suggest that current vehicle emission rates may change significantly over time. The internal combustion engine is expected to become significantly cleaner to operate. Also, electric vehicles are a distinct possibility, although it should be remembered that pollution-producing generating plants are required to produce the electrical energy that would operate these vehicles. In spite of these possibilities, we have elected to illustrate our methodology in terms of an extrapolation of current-day automotive experience. Alternative assumptions could be introduced if desired.

An additional burden from automotive emissions is imposed on those who live or work near heavily traveled roads. However, there is evidence that the excess concentration occurs only within 50 feet of the pavement. We can assume there are no residences or jobs this close to a freeway.

Table 37

DISTRIBUTION OF PEOPLE AFFECTED BY AUTOMOTIVE AIR POLLUTION ON A WORKING DAY: CITY TYPE 3

	Ring 1			*Ring 2*		
Income Class[a]	*Nonworking Population*	*Working Population*	*Total*	*Nonworking Population*	*Working Population*	*Total*
< $4K	101,000	56,700	157,700	23,300	18,900	42,200
$4-$10K	310,900	212,700	523,600	155,500	212,800	368,300
$10-$20K	124,400	181,600	306,000	298,500	105,800	404,300
> $20K	31,100	56,700	87,800	62,200	17,400	79,600
Total	567,400	507,700	1,075,100	539,500	354,900	894,400

[a]Annual family income.

Airplane-caused air pollution is localized around the landing path near the airport. We assume an affected area of the dimensions shown in Fig. 9. The shaded area at the center of a rectangle of 3 × 1.5 mi includes the airport and associated industrial and commercial areas; no residences are within this rectangle. Residential areas are affected for a mile on either side, and to two miles at either end of this core. Hence, the total area affected is 7 × 3.5 = 24.5 sq mi, of which 20 sq mi is residential. We shall assume an incremental worth of -.1 within this total area.

The airport is located at the outer edge of ring 2, so the residential density is 5600 persons per sq mi from Table 6. Assuming that airplane-caused smog is constant throughout the week, all residents suffer whether employed or not. Hence, 5600 × 20 = 112,000 residents affected. In addition, there are 20,000 employees at the airport and in the surrounding industrial areas. Suppose 15,000 of these live

outside the affected residential area; these people are also assigned an incremental worth of -.1.*

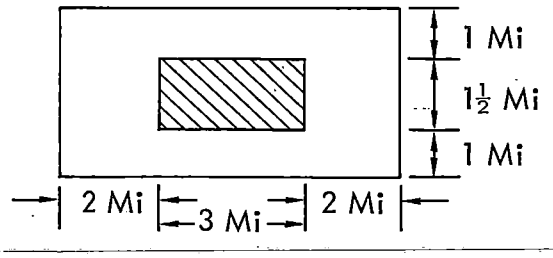


Fig. 9--Area affected by air pollution near an airport

Using the income breakdown in ring 2 by residence and employment from Table 7, we get the numbers of people affected, as shown in Table 38.

Table 38

PEOPLE AFFECTED BY AIRPLANE AIR POLLUTION

Income Group	*Residential Population*	*Employment Population*	*Total Total*
< $4K	4,480	750	5,230
$4-$10K	32,480	9,000	41,480
$10-$20K	61,600	4,500	66,100
> $20K	13,440	750	14,190
Total	112,000	15,000	127,000

Since all of these people have a background automotive air pollution worth of -.1, their total worth is -.2. Assuming that there is no significant air pollution from the railroad and that automotive pollution is the combined impact of automobiles and buses, we determine that a type 3 city with one airport has a distribution of air pollution worth units, by income group, as shown in Table 39.

*No assumption has been made concerning possible redistribution of the residential population out of the airport area in a fashion so that overall density statistics, such as those shown in Table 6, would be maintained.

Table 39

THE DISTRIBUTION OF AIR POLLUTION EFFECTS

BASE MIX OF MODES: CITY TYPE 3

Income Group	*Number of People* At -.2 Worth Level	At -.1 Worth Level
< $4K	162,900	37,000
$4-$10K	565,100	326,800
$10-$20K	372,100	338,200
> $20K	102,000	65,400
Total	1,202,100	767,400

This information may be condensed even further if we wish to assume that worth units, like dollars, are additive across individuals. Performing this addition, we get the following aggregate worths:

Income Group	*Aggregate Worth*
< $4K	-36,300
$4-$10K	-145,700
$10-$20K	-108,200
> $20K	-26,900
Total	-317,100

We might expect the following changes in impact upon type 3 cities if other modes are introduced. The addition of TACV and STOL service, while affecting intercity automobile use, would not have much effect on use of the automobile on the short intracity trips that generate most of the concentrated smog problem. It would put airports into 17 of the 24 cities instead of just the 5 assumed in the base mix. On the other hand, our hypothetical city already has an airport, so the effect would be virtually nil.

Addition of a dual-mode system could be expected to cut the local smog problem, since many people would own the electric cars and would use them when driving on city streets. Assuming competition between the electric and the gasoline automobiles and no restrictive legislation against the gasoline auto, automotive air pollution might be cut in half--

i.e., the ring 1 level is reduced to -.1 and the ring 2 level to -.05. Table 40 shows the distribution and the aggregate effects with these assumptions introduced.

Table 40

THE DISTRIBUTION OF AIR POLLUTION EFFECTS

DUAL-MODE MIX: CITY TYPE 3

	Number of People			
Income Group	*At -.15 Worth*	*At -.1 Worth*	*At -.05 Worth*	*Aggregate Worth*
< $4K	5,200	157,700	37,000	-18,400
$4-$10K	41,500	523,600	326,800	-74,900
$10-$20K	66,100	306,000	338,200	-57,400
> $20K	14,200	87,800	65,400	-14,200
Total	127,000	1,075,100	767,400	-164,900

In extending this analysis region-wide, we need to estimate how the air pollution worth values would vary among city types. We would expect that the smaller cities would have lower automotive smog levels than the larger ones because their population densities are lower. In addition, they would have lower airplane smog levels because of fewer operations per hour.* Table 41 presents some postulated pollution levels by city type.

Table 41

POLLUTION LEVELS BY CITY TYPE

	Automotive		
City Type	*Ring 1*	*Ring 2*	*Airplane*
1	-.2	-.1	-.1
2	-.2	-.1	-.1
3	-.2	-.1	-.1
4	-.1	-.05	-.05
5, 6	Negligible		

*In a more detailed analysis, airport smog levels would actually be estimated in terms of the number of operations per hour, which could be derived using link flow information from the user analysis.

Using these levels, tables similar to 39 and 40 can be generated for the other city types. Table 42 presents the number of people affected at various intensity levels by city size assuming each of the three mixes of modes. Since New York City has three airports, we multiply the airport effects by three for city type 1. Cities of types 2 and 3 always have one airport; cities of type 4 may or may not have an airport, depending on whether STOL service exists.

Table 42

NUMBER OF PEOPLE PER CITY AFFECTED BY AIR POLLUTION
(In thousands)

City	Base Mix and TACV/STOL Mix		Dual-Mode Mix		
	-.2 Worth	-.1 Worth	-.15 Worth	-.1 Worth	-.05 Worth
City Size 1					
< $4K	1096	263	24	1072	263
$4-$10K	3749	2316	189	3560	2316
$10K-$20K	2401	2429	321	2080	2429
> $20K	666	472	69	597	472
Total	7912	5480	603	7309	5480
City Size 2					
< $4K	385	94	7	378	94
$4-$10K	1308	832	52	1256	832
$10-$20K	821	883	87	734	883
> $20K	230	172	19	211	172
Total	2744	1981	165	2579	1981
City Size 3					
< $4K	163	37	5	158	37
$4-$10K	565	327	42	524	327
$10-$20K	372	338	66	306	338
> $20K	102	65	14	88	172
Total	1202	767	127	1076	1981
	-.1 Worth	-.05 Worth			
City Size 4 (Airport)					
< $4K	41	7	-	-	3
$4-$10K	152	62	-	-	26
$10-$20K	111	59	-	-	38
> $20K	29	11	-	-	8
Total	333	139	-	-	75
City Size 4 (No Airport)					
< $4K	38	10	-	-	-
$4-$10K	126	88	-	-	-
$10-$20K	73	97	-	-	-
> $20K	21	19	-	-	-
Total	258	214	-	-	-

V-9

Table 43 summarizes the air pollution effects over the entire region, The summary is for Regional Environment A, the mix of modes including TACV/STOL, in the year 2000. In Table 42, the number of people affected is multiplied by the number of cities of each size. Values are presented for the number of people "seriously annoyed--i.e., at the -.2 worth level only, and then for the total worth units.

Table 43

NETWORK-WIDE AIR POLLUTION SUMMARY

(Regional Environment A, TACV/STOL Mix, Year 2000)

Group	*Number of Cities*	*Number of People Seriously Annoyed (-.2 Worth Level) (thousands)*		*Total Worth Units (Negative Numbers) (thousands)*	
		Per City	*Region-Wide*	*Per City*	*Region-Wide*
Poverty (<$4K)					
City Size 1	1	1,100	1,100	246	246
City Size 2	2	390	780	86	172
City Size 3	1	160	160	36	36
City Size 4[a]	5		0	4	20
City Size 4[b]	3		0	4	12
Total			2,040		486
Lower Income ($4-$10K)					
City Size 1	1	3,750	3,750	981	981
City Size 2	2	1,310	2,620	345	690
City Size 3	1	570	570	146	146
City Size 4[a]	5		0	18	90
City Size 4[b]	3		0	17	51
Total			6,940		1,958
Middle Income ($10-$20K)					
City Size 1	1	2,400	2,400	723	723
City Size 2	2	820	1,640	253	506
City Size 3	1	370	370	108	108
City Size 4[a]	5		0	14	70
City Size 4[b]	3		0	12	36
Total			4,410		1,443
Upper Income (> $20K)					
City Size 1	1	670	670	180	180
City Size 2	2	230	460	63	126
City Size 3	1	30	30	27	27
City Size 4[a]	5		0	3	15
City Size 4[b]	3		0	3	9
Total			1,160		357
GRAND TOTAL			14,550		4,244

[a] With airport.

[b] No airport.

Table 44 carries the worth summary one step further. Here the three mixes are compared, over the 1970-2000 time horizon, assuming Regional Environment A. The step-function appearance of these numbers over time results from our approximation of each city type by a single average population number. Thus, a city may grow in population, but if it remains in the same city size class, this growth is not shown in these figures. The use of a computer would make this approximation unnecessary.

Table 44

AIR POLLUTION WORTH SUMMARY

(Regional Environment A)

5-Year Accumulations of Worth Units (Negative Numbers) (in thousands)

Mix	*1970-75*	*1975-80*	*1980-85*	*1985-90*	*1990-95*	*1995-2000*
Base Mix	18,830	18,830	19,010	21,160	21,160	21,160
TACV/STOL Mix	18,830	18,830	19,010	21,190	21,220	21,220
Dual-Mode Mix	18,830	18,830	9,950	9,235	9,055	9,055

The slight increase in negative worth units for the TACV/STOL mix over the base mix is caused by the addition of numerous STOL airports to the network. The sharp decrease displayed by the dual-mode mix is caused by partial replacement of gasoline autos by the electric autos of the dual-mode system.

NOISE: A CONTINUUM FROM QUALITATIVE TO QUANTITATIVE MEASUREMENT

We turn now to analyzing societal impacts in terms of the attribute *noise.* Our purpose in this subsection is to apply a range of measurement methods to a common example. These methods are discussed in Sec. V of Vol. II and are as follows: systematic qualitative evaluation, direct worth estimation, quantification in physical units and a complete worth estimation procedure based on a spatial partition of the region. The example we use is the mix of modes with TACV and STOL services added and assuming Regional Environment A.

Systematic Qualitative Evaluation

The method of systematic qualitative evaluation is, simply, to survey, by whatever means available--i.e., reading of detailed studies, observation, discussion with experts, etc., all the noise effects of the mix of modes and to summarize in a sentence or two the significant differences from the base mix. The significant additions to noise levels from the TACV/STOL additions impact on those who live near new TACV links and new STOL airports. This impact starts with the inauguration of service in 1980 and increases thereafter. Hence, a brief summary statement could be as follows:

> New TACV links and STOL airports add a consideration increment to the number of people affected by noise. This increment starts in 1980 and increases as service is extended to additional links in the network.

In an overall evaluation, brief summaries of this type would be prepared, in terms of each societal attribute, for each of the alternatives being compared. This information could be presented in a form suitable for easy analysis as illustrated in Sec. V of Vol. II.

Direct Worth Estimation

The method of direct worth estimation can be used to assess the impact of noise throughout the region. This can be done in terms of interests of society as a whole as interpreted by regional planners and decisionmakers. The worth score produces a single subjective judgment regarding the effect of the alternative mix of modes in terms of the attribute. Worth scores of this form are given for all attributes in the illustration of region-wide direct worth analysis included in Sec. VI. In that analysis we use a 0 to 1.0 worth scale. This removes the confusion that may arise in working with negative values. Thus, a larger positive number is always better and, in this instance, indicates larger levels of undesirable noise. In the analysis in Sec. VI, estimates of the region-wide impact of noise in the year 2000 for the TACV/STOL mix as compared with the other mixes are as follows:

Mix	*Worth*	*Weighted Worth*
Base mix extrapolated	.6	42
TACV/STOL mix	.5	35
Dual-mode mix	.8	56

where noise is assigned a weight of 70 out of 1000 points available for division among all societal attributes.

This method is useful in producing a qualitative evaluation quickly, especially if the systematic qualitative evaluation described above has been performed and there is a need for assessing the relative significance of the brief qualitative summaries on each attribute.

When performed in this aggregate fashion, however, the direct worth method does not produce any information on how many people are affected, on where within the region the effects might occur, or on the range of seriousness or intensity of the effects. It is simply a quick way of assembling judgments in a quantitative fashion. If we were concerned with analyzing the societal impacts of adding a single new mode in a single city, for example, building a STOL port, then the lack of availability of information on distribution of the effects would be less serious than it probably is in assessing the region-wide impact of an entire mix.

Quantification in Physical Units

Quantification in physical units requires specific engineering information about the noise generated by the modes involved. Let us assume that in our period of analysis, 1980-1985, the three important intercity mode sources of noise will be freeways, airports, and TACV lines.

The following noise evaluation model for freeways was constructed using a basic reference on freeway noise [12]. We assumed an 8-land freeway passing at ground level through a residential area, with a traffic flow of 6000 vehicles per hour, which is heavy--but not rush-hour--traffic, and an average speed of 60 mph.* Assuming the

*Eventually, this data should be derivable from the link flow information generated in user analyses.

traffic stream was composed wholly of automobiles, we estimated a mean noise level of 71 dBA* at 100-ft distance from the stream. Traffic with 10% diesel trucks increased this to 75 dBA.

It was found empirically that the noise changed by $-15 \log_{10} d/d_o$ decibels when the distance changed from d_o to d. The distance is measured from a hypothetical one-lane traffic stream that is equivalent to the whole freeway and located 2.8-lane-widths beyond the center line of the nearest lane. This means that for 12-ft-wide lanes, the effective location of the noise is 40 ft in from the edge of the nearest traffic lane.

The resulting noise levels at various distances from the edge of the nearest traffic lane are as follows:

Distance from Freeway Equivalent Source (ft)	*Distance from Edge of Near Lane (ft)*	*Mean dBA*
90	50	76
100	60	75
140	100	73
240	200	69
440	400	65

Surveys discussed in Ref. 12 show that practically no one lives closer than 50 ft from the edge of a freeway. We shall assume that the residential densities in Table 6 apply over the 50- to 400-ft distance on either side of the freeway, and that this distance is a reasonable estimate of the range in which freeway noise is annoying.

Thus, each freeway has annoying noise effects in a 700-ft-wide band. Using Table 3 we can calculate how many square miles are affected in each city type and ring, and the information in Tables 4 and 6 allows us to estimate how many people are affected in these cities by income group. The results are given in Tables 45 and 46.

*The dBA is a standard measure of noise that averages over the noise frequency spectrum. It is highly correlated with people's perceived loudness. Data is taken from Fig. 3 of Ref. 12.

Table 45

SQUARE MILES PER CITY AFFECTED BY FREEWAY NOISE

City Type	Ring 1	Ring 2	Ring 3
1	1.32	2.65	3.98
2	.88	1.76	2.65
3	.66	1.32	1.98
4	.44	.88	1.32
5	.353	.71	1.06
6	.265	.53	.80

Table 46

NUMBER OF PEOPLE PER CITY AFFECTED BY FREEWAY NOISE

	Group			
City Type	<$4K	≥$4 <$10K	≥$10 <$20K	≤$20K
1	20,450	71,040	38,250	8,860
2	10,820	37,560	20,240	4,690
3	6,020	20,960	11,300	2,620
4	2,150	7,430	4,000	930
5	720	2,500	1,360	310
6	240	820	450	100

In addition, there are 543 rural miles of the freeway system, which, at an assumed rural density of 100 persons per square mile and a ring 3 distribution, result in the following numbers of people affected:

Income Group	No. of People
>$4K	500
≥$4 <$10K	5000
≥$10 <$20K	1250
≥$20K	400

In 1980-85 for Regional Environment A, there are the following numbers of cities of different types and all of these are assumed to have freeways:

City Type	*Number of Cities*
1	1
2	1
3	2
4	8
5	6

Therefore, we can find the total number of people affected by income group. Of these, the data show that about one-seventh experience mean noise levels of 73-76 dBA, two-sevenths experience 69-73 dBA, and four-sevenths experience 65-69 dBA. Table 47 gives the total number of people influenced at these levels, by income group. This is a final quantitative summary of freeway noise in physical units, in the 1980-85 time period.

Table 47

TOTAL NUMBER OF PEOPLE AFFECTED BY FREEWAY NOISE AT DIFFERENT LEVELS (1980-85)

Mean Noise Level	*Distance (ft)*	*>$4K*	*≥$4<$10K*	*≥$10<$20K*	*≥$20K*	*Total*
				(in thousands)		
73-76 dBA	50-100	9.3	32.8	17.5	4.1	63.7
69-73 dBA	100-200	18.7	65.7	35.0	8.1	127.5
65-69 dBA	200-400	37.3	131.5	70.0	16.3	255.1
Total		65.3	230.0	122.5	28.5	446.3

For *airport* noise, we used as a criterion the maximum perceived noise level from an individual jet aircraft in takeoff or landing, loaded for short and medium distance flights (< 1000 mi). We have assumed the conventional method of plotting noise contours.* Although one might expect STOL aircraft to have different noise contours, these aircraft, which require greater power for a steeper glide slope, generate about the same noise levels on the ground as the more slowly ascending jets.

*Such contours are given in Fig. 1 of Ref. 13 reprinted from Ref. 14.

We have assumed 90 PNdB* as a lower limit of annoyance for peak intermittent noise from aircraft. For simplicity in illustration, aircraft peak noise below this level is ignored. Figure 10 adapts the airport model of Fig. 9 to the noise problem, using the noise contours previously identified. The area inside this contour is estimated at 34 sq mi, and inside the 100 PNdB contour at 15 sq mi. In this illustration, the shaded non-residential area in Fig. 10 occupies 4.5 sq mi, so the residential area affected is 29.5 sq mi. Out of this, the area inside the 105 PNdB contour is estimated as 4 sq mi, and the area from 100 to 105 PNdB is 6.5 sq mi.†

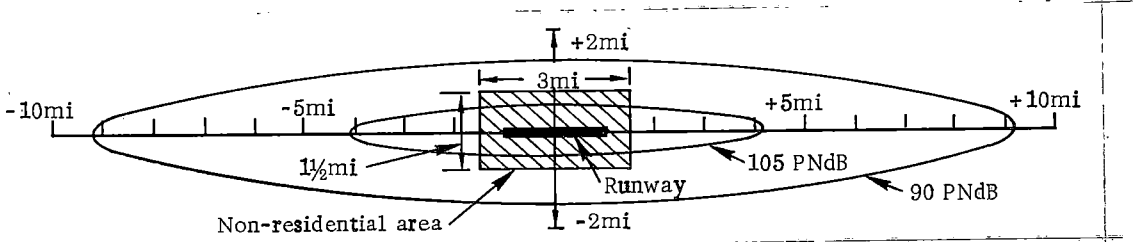


Fig. 10--Noise contours around an airport

In the 1980 to 1985 time period, we have assumed there are seven airports with scheduled commercial air service--three in New York City (city type 1), one in Philadelphia (city type 2), two in Baltimore-Washington (city type 3), and one in Harrisburg (city type 4). Assuming these airports are near the outer edge of Ring 2, we can use the residential densities in Table 6 and the income group breakdowns in Table 7 to find the number of people affected in the region. Table 48 presents these numbers.

*PNdB, i.e., perceived noise expressed in decibels, is a noise measure similar to dBA, commonly used for aircraft measurements.

†Figure 10 is just an illustration. Obviously, for larger airports with multiple runways the overall contours might be more nearly star-shaped or even circular.

Table 48

TOTAL NUMBER OF PEOPLE INFLUENCED BY AIRCRAFT NOISE AT DIFFERENT LEVELS (1980-85)

Peak Intermittent Noise Level	*Area Near Airport (sq mi)*	*Thousands of People*				
		<$4K	*≥$4<$10K*	*≥$10K<$20K*	*≥$20K*	*Total*
> 105 PNdB	4.0	8.0	57.9	109.8	23.9	199.6
100-105 PNdB	6.5	13.0	95.8	178.4	38.8	326.0
90-100 PNdB	19.0	34.0	246.0	466.3	101.5	847.8
Total	29.5	55.0	399.7	754.5	164.2	1,373.4

The noise analysis for the TACV system is similar to the highway analysis in being based on bands near the right-of-way. It is similar to the airport analysis in being an intermittent noise source. The peak intermittent noise levels from TACV are assumed to be as follows:*

Distance (ft)	*PNdB*
50	110
120	105
200	100
600	90

Assuming again that affected residences lie no closer than 50 ft from the source, the affected band will be 50 to 600 ft on either side of the right-of-way (assuming the same 90 PNdB annoyance threshold as in the airport case).

Thus the areas and the number of people affected, for each city type, given in Tables 46 and 47 are scaled up by the ratio of the TACV band width of 1100 ft to the freeway band width of 700 ft.

In the 1980-1985 time period, the TACV system serves the Washington to New York chain of cities, with the following numbers of cities of different types:

City Type	*Number of Cities*
1	1
2	1
3	2
4	3

*From Lago, Ref. 15, pp. 16, 20

There are 45 rural mi of TACV routing in 1980-85, resulting in the following number of people affected:

Income Group	*Number of People*
<$4K	60
>$4<$10K	650
>$10<$20K	160
>$20K	50

Hence, we can find the total number of people affected and identify them by income group. Of these, the data show that 12.7 percent experience noise levels > 105 PNdB, 15.5 percent experience noise levels of 100-105 PNdB, and 72.8 percent experience noise levels of 90-100 PNdB. Table 49 gives the total number of people involved.

Table 49

TOTAL NUMBER OF PEOPLE AFFECTED BY TACV NOISE AT DIFFERENT LEVELS (1980-85)

Peak Intermittent Noise Level	*Distance (ft)*	<$4K	>$4K<$10K	>$10<$20K	>$20K	*Total*
		(in thousands)				
> 105 PNdB	50-120	10.0	34.6	18.7	4.4	67.7
100-105 PNdB	120-200	11.4	39.6	21.2	4.9	77.1
90-100 PNdB	200-600	56.9	198.0	106.5	24.7	386.1
Total		78.3	272.2	146.4	34.0	530.9

Tables 47, 48, and 49 combined present an estimate of the total impact of noise produced by the mix of modes which includes TACV and STOL service. This information is presented in terms of the number of people affected by level of effect, expressed in physical units, i.e., decibels.

Worth Estimation Procedure

The worth estimation procedure illustrated next assigns worth numbers to the effects calculated above in physical units. In addition, a weight may be assigned to noise relative to other attributes.

Worth levels of .2, .5 and .8 are assigned to the three bands of each type of noise, as illustrated in Table 50.

Table 50

WORTH CORRESPONDENCE TO PHYSICAL UNITS

Worth Level	*Worth Range*	*Noise Range* *Freeway*	*Airport-TACV*
.2	.1 to .3	73-76 dBA	> 105 PNdB
.5	.3 to .7	69-73 dBA	100-105 PNdB
.8	.7 to .9	65-69 dBA	90-100 PNdB

A weight of 71 points out of 1000 is assigned to noise, as shown in the illustration of comprehensive worth assessment in Sec. VI. In addition to the affected people listed in Tables 47, 48, and 49, there are a large number of people virtually unaffected by noise who are assigned a worth of 1.0. From Table 2 we see that the total number of people in the region at mid-point in the 1980-85 time period is about 37.0 million, hence we can infer the number of unaffected people.

Table 51 shows the aggregate worth evaluation. Since worth scores are on a 0 to 1 scale, the unaffected people must be added to the others for a comparison with other mixes of modes. For an incremental comparison, however, only *changes* in the number of unaffected people are important.

Table 51

AGGREGATE WORTH EVALUATION BY TYPE OF NOISE

(in thousands)

	Poverty		*Lower Income*		*Middle Income*		*Upper Income*		*Total*	
Noise Type	*People*	*Worth*	*People*	*Worth*	*People*	*Worth*	*People*	*Worth*	*People*	*Worth*
Freeway	65	2,910	230	10,270	123	5,470	28	1,270	446	19,920
Airport	55	2,510	400	18,200	754	34,380	164	7,480	1,373	62,570
TACV	78	3,780	272	13,140	147	7,070	34	1,640	531	25,630
Subtotal	198	9,200	902	41,610	1,024	46,920	226	10,390	2,350	108,120
Unaffected	3,474	246,650	17,458	1,239,520	10,726	761,550	2,712	192,550	34,370	2,440,270

STRUCTURING THE HOUSING ATTRIBUTE

This subsection has the purpose of examining a preliminary detailed list of lower-level measures of housing quality and quantity, and of demonstrating the indirect effects of transportation on these measures through mechanisms such as disposable personal income.

In measuring and evaluating the effect of transportation performance on housing, one must recognize both effects that are clearly related *only* to housing and effects that have their own measure of worth but can still exert an influence on housing. Items such as air pollution, noise, displacement, property values, personal income, population redistribution, and government supplied servcies all have been considered as societal attributes separate from the attribute *housing*. It should be recognized that a change in any of these attributes, as caused by the transportation system, may exert an indirect influence upon housing in addition to any direct effects of transportation. In fact, the indirect or second order effects on housing probably are the dominant ones.

As new transportation facilities are introduced into a community, they will cause changes in land usage, residential patterns and industrial development, among others, and will have an influence on both the local and the metropolitan economy. New housing construction will be undertaken and some existing homes will be demolished to make way for the new transportation facility.

The quality and quantity of housing may well be changed by placing the new transportation system into operation. Before outlining possible changes, two important relationships should be clarified, namely housing as it relates to land values on the one hand, and to population density on the other. Land in close proximity to a new transportation system will increase in value as business districts and industrial complexes become more accessible, and as new land areas are opened for settlement and development. At the opposite end of this spectrum, other land will decrease in value because of undesirable aspects of noise and air pollution and other physical damage. There will be a shift in population since the new transportation system will have a direct effect on community growth. Changes in income resulting from accessibility of new

job markets, and displacements by the new system will cause further population redistribution.

The quantity and quality of housing available to an individual are largely a function of his personal income. Income considerations are paramount in determining an individual's capacity to react to transportation effects on housing, regardless of his attitude toward the effect of other societal attributes on his housing situation. Personal income can be increased because the new transportation system opens new job markets thus increasing demand for labor, or by an indirect increase in *real* income because the transportation system makes it cheaper to travel to work--because either the job is closer or the cost of using the new system is less than that of older systems.

Once the transportation system has exerted its effects on personal income, the question is to determine how incremental income may be used to improve the housing situation. An individual has various preferences with regard to housing, many of which can be described by the following basic considerations:

- o Single-family vs. multi-family.
- o Number of rooms and bedrooms.
- o Type of facilities, e.g., plumbing, parking, heating.
- o Style.
- o Landspace and landscaping.
- o Amount and quality of furnishings.

To determine how housing preferences are affected by income, one must first enumerate these preferences and establish some physical measures for them at various income levels. The extent to which the measured values change with level provides some indication of the sensitivity of preferences to income. The list of measurements in Table 52 provides some insights into housing measures that might be considered and digested in determining how any incremental income would be spent.

This list, of course, shows only those housing characteristics on which incremental income might be spent. Neither this list nor the discussion below provides any specific information on the priority ranking of the various characteristics. Ranking would depend on the housing

Table 52

HOUSING MEASUREMENTS

Measures of Housing Quality	*Unit of Measurement*
Number of rooms	Individuals per room; rooms per dwelling unit
Floor space	Ratio of persons to floor space; floor space per dwelling
Inside toilet facilities (indoor plumbing)	Fraction of dwelling units with indoor plumbing
Number of bedrooms	Individuals per bedroom
Kitchens	Fraction of dwelling units with modern kitchens
Land space (size of lot)	Amount of land per dwelling unit
Landscaping	Fraction of dwelling units with standard landscaping
Parking facilities On street Off street Sheltered	Number of auto spaces per dwelling unit or fractions of total housing supplied with this kind of parking
Type of house Brick Frame (& stucco) Combination	Fractions of total housing supply
Household furnishing	Value per dwelling unit
Style Ranch Colonial Multi-floor Others	Fractions of total housing supply
Basement; utility room; recreation room; and family room	Fractions of total housing supply
Types of heating plants Oil Gas Electric Coal	Fractions of total housing supply
Apartment styles Hi-rise Garden	Fractions of total housing supply
Age of dwelling unit	Distribution of ages
Types of dwelling units Single-family (private) Multi-family (private) Single-family (public) Multi-family (public)	Number of persons per room per type of dwelling unit
Land space	Number of persons per measurable land space, e.g., acre
Construction activity (e.g., housing starts)	Rate of housing starts
Standard vs. substandard	Fraction of standard housing

and income level at which an individual starts, together with the amount of incremental income provided. Given a certain housing condition, personal income, and various levels of incremental income, probability distributions could be developed indicating how the incremental income, if spent on improving housing conditions, would be allocated among housing characteristics. Further research is needed on this point and the following is only suggestive of the considerations incremental income can have on housing.

Increases in family income may be expected to elevate a family's living pattern so the family seeks better living quarters. This includes both better quality and greater quantity in housing. Private homeownership, which is considered by many Americans as a goal, takes on new meaning with additional income. Home ownership instills pride and a sense of accomplishment, although it is realized apartment (rental) living is preferred by many persons capable of home ownership.

To trace the effect of incremental increases in family income relative to selected housing characteristics, Table 53 illustrates that an increase in income raises the quality and quantity of housing. The table is based on the 1960 Housing Census data for the Philadelphia, Washington, D. C., and Los Angeles SMSA's; and it presents data for only owner-occupied dwellings. It should be noted that the number of rooms per person in the lowest grouping appears large; however, a large number of senior citizens are included in this grouping and many senior citizens live alone.

Table 53

BASIC MIX OF HOUSING CHARACTERISTICS: OWNER OCCUPIED DWELLINGS

	Family Income											
	< $4,000			*≥ $4,000 < $10,000*			*≥ $10,000 < $20,000*			*≥ $20,000*		
Characteristic	*SMSA*	*Ring 1*	*Ring 2*	*SMSA*	*Ring 1*	*Ring 2*	*SMSA*	*Ring 1*	*Ring 2*	*SMSA*	*Ring 1*	*Ring 2*
Rooms/person, no.	1.85	1.90	1.4	1.85	1.84	1.7	1.97	1.88	2.0	2.3	2.24	2.2
Rooms/dwelling, no.	5.2	5.4	4.3	6.0	6.0	5.1	6.3	6.4	6.0	7.0	7.4	6.8
Bedrooms/dwelling, no	2.7	2.6	2.5	3.0	3.0	2.6	3.2	3.2	2.9	3.5	3.7	3.5
Bathrooms/dwelling, no.	.9	1.0	1.0	1.2	1.1	1.2	1.6	1.6	1.4	1.9	1.8	1.8
Condition of bathrooms and plumbing												
Sound, %	.80	.81	.70	.96	.96	.92	.985	.99	.98	.99	.995	.995
Deteriorating, %	.20	.19	.30	.04	.04	.08	.015	.01	.02	.01	.005	.005

Note: Based on 1960 Housing Census Data for the Philadelphia, Washington, D.C., and Los Angeles SMSA's.

New modes of transportation may well exert an important influence on housing through changes in economic conditions, desirability of living conditions, and individuals' preference patterns. The ability of individuals to react is strongly related to the effect of the transportation system on their income, a similar process of analysis could be undertaken to identify indirect mechanisms of effect on other societal attributes. In each case the search is for a few dominant influences of transportation on the attribute and a set of useable measures of these effects.

VI. COMPREHENSIVE EVALUATIONS OF SOCIETAL BENEFIT*

INTRODUCTION

In this section we illustrate two methods for comprehensive evaluation of societal benefits. The first is a direct worth analysis, which provides a single subjective estimate of the region-wide worth of each alternative in terms of each attribute. The second method is a spatially-oriented evaluation, which estimates both the intensity of the effect and the number of people affected in each link band, city ring, and other segment of the region.†

DIRECT WORTH EVALUATION

The direct worth evaluation consists of two major steps. In the first step, we estimate worth by asking the question: "From the point of view of society, how good a result is achieved with respect to this attribute (on a 0 to +1.0 scale) if a given mix of modes is introduced and assuming a given regional environment and time period?" In the second step, weights are determined by asking another question: "From the point of view of society, how important is a worth of +1.0 for this attribute relative to a worth of +1.0 for other attributes."‡

Table 54 gives the results of this analysis. For Regional Environments A and B, we calculated the worth of the current mix in 1970

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*Further discussion of the methodology used in this Section is provided in Sec. VII of Vol. II. Section V of Vol. II may also be useful as a reference on the reasoning underlying the measurement approaches utilized.

†The direct worth analysis of all societal attributes for the three mixes of modes and the two regional environments took about one man-day of work. The spatially-oriented evaluation took about a man-month and required some computer assistance to facilitate the calculations. This points up the real difference between the methods: quick results versus increased reasonableness.

‡Scaling and weighting conventions helpful in ensuring consistency in performing these two steps are discussed in detail in Sec. VIII (including its appendix) of RM-5869-DOT (Ref. 5). The estimates are furnished by informed analysts or decisionmakers applying judgment. Ultimately, if they were available, the inputs might also be gathered using carefully structured survey methods.

See also the discussion on "Direct Worth Estimation" under the subsection on *Noise* in Sec. V of this Volume.

Table 54

DIRECT WORTH ANALYSIS OF SOCIETAL ATTRIBUTES

		Current Mix, 1970		Extrapolated Current Mix, 2000		TACV/STOL Added, 2000		Dual-Mode Added, 2000	
	Weight	Worth	Weighted Worth	Worth	Weighted Worth	Worth	Weighted Worth	Worth	Weighted Worth
Regional Environment A									
Human physiology	70	0.5	35	0.4	28	0.4	28	0.7	49
Air pollution	70	0.5	35	0.4	28	0.4	28	0.7	49
Noise pollution	70	0.7	49	0.6	42	0.5	35	0.8	56
Accidents to non-users	20	0.9	18	0.9	18	0.8	16	0.9	18
Right-of-way associated									
Partitioning	20	0.8	16	0.6	12	0.7	14	0.8	16
Displacement	40	0.8	32	0.8	32	0.8	32	0.8	32
Construction inconvenience	20	0.9	18	0.9	18	0.9	18	0.9	18
Property values	30	0.8	24	0.6	18	0.5	15	0.8	24
Economic									
Employment	50	0.4	20	0.5	25	0.7	35	0.7	35
Personal income	90	0.6	54	0.7	63	0.8	72	0.8	72
Industrial distribution	40	0.6	24	0.5	20	0.7	28	0.5	20
Population distribution	40	0.4	16	0.2	8	0.2	8	0.2	8
Metropolitan form & design									
Land use distribution	40	0.4	16	0.3	12	0.4	16	0.4	16
Housing	70	0.7	49	0.5	35	0.5	35	0.5	35
Metropolitan design	30	0.4	12	0.6	18	0.8	24	0.7	21
Sociological-political									
Individual life style	70	0.7	49	016	42	0.8	56	0.9	63
Community involvement	50	0.5	25	0.4	20	0.5	25	0.5	25
Governmental form	30	0.5	15	0.4	12	0.7	21	0.4	12
Tax policy	40	0.6	24	0.5	20	0.5	20	0.5	20
Gov't supplied services	50	0.6	30	0.5	25	0.5	25	0.5	25
Scarce resources									
Radio reception	20	0.9	18	0.9	18	0.7	14	0.8	16
Electric power capacity	40	1.0	40	0.9	36	0.7	28	0.7	28
Ecology	70	0.7	49	0.5	35	0.6	42	0.6	42
Total	1000		633		557		607		651
Regional Environment B									
Human physiology									
Air pollution	70	0.5	35	0.4	28	0.4	28	0.7	49
Noise pollution	70	0.7	49	0.6	42	0.5	35	0.8	56
Accidents to non-users	20	0.9	18	0.9	18	0.8	16	0.9	18
Right-of-way associated									
Partitioning	20	0.8	16	0.6	12	0.7	14	0.8	16
Displacement	40	0.8	32	0.8	32	0.8	32	0.8	32
Construction inconvenience	20	0.9	18	0.9	18	0.9	18	0.9	18
Property values	30	0.8	24	0.8	24	0.7	21	0.9	27
Economic									
Employment	50	0.4	20	0.5	25	0.7	35	0.7	35
Personal income	90	0.6	54	0.7	63	0.8	72	0.8	72
Industrial distribution	40	0.6	24	0.8	32	0.9	36	0.8	32
Population distribution	40	0.4	16	0.7	28	0.8	32	0.8	32
Metropolitan form & design									
Land use distribution	40	0.4	16	0.7	28	0.8	32	0.8	32
Housing	70	0.7	49	0.8	56	0.8	56	0.8	56
Metropolitan design	30	0.4	12	0.8	24	0.9	27	0.8	24
Sociological-political									
Individual life style	70	0.7	49	0.8	56	0.9	63	1.0	70
Community involvement	50	0.5	25	0.7	35	0.8	40	0.8	40
Governmental form	30	0.5	15	0.6	18	0.8	24	0.6	18
Tax policy	40	0.6	24	0.7	28	0.7	28	0.7	28
Gov't supplied services	50	0.6	30	0.7	35	0.7	35	0.7	35
Scarce resources									
Radio reception	20	0.9	18	0.9	18	0.7	14	0.8	16
Electric power capacity	40	1.0	40	0.9	36	0.7	28	0.7	28
Ecology	70	0.7	49	0.7	49	0.8	56	0.8	56
Total	1000		633		705		741		790

and the worths of the three alternative future mixes in the year 2000. These three sets of weighted worths in 2000 can be regarded as the end points of a worth assessment that changes over time. A rough estimate of values in intermediate time periods can be made by interpolation.

A major benefit of performing a direct worth assessment of this kind is not so much the numbers that result, but the understanding that accompanies the process of getting the numbers. Behind every number is a set of assumptions often made quite explicitly. The documentation of these assumptions can be very helpful to a decisionmaker in reaching his decision.

SPATIALLY-ORIENTED EVALUATION

The spatially-oriented evaluation illustrated in this example involves four major steps. First, the region must be divided into segments and modal service specified in a rational and systematic way. Then a worth estimate is prepared for each of the attributes in each division of the region. The third step is calculation of the incidence, or the number of people affected, at each worth level. Finally, the products of worth and incidence estimates are summed over all regional divisions and all attributes to give measures of aggregate worth.

Partitioning the Region and Specifying Modal Service

In this method, the region is partitioned for three kinds of effects. The first is a link effect, that is, any effect such as noise or displacement that occurs close to the network links. The link effects are partitioned using three bands. Standard band widths for each mode are as follows:

	Band Width (ft)	
Band	Dual Mode	All Other Modes
1	70	100
2	280	400
3	490	700

Band 2 is always four times the width of Band 1, and Band 3 is seven times the Band 1 width. We assume the same spatial partition for all attributes, an approximation that simplifies the computation considerably.*

The second effect is the *citywide* effect. This captures diffuse effects like population and industrial distribution that vary across the city but are not particularly link-related. We use the partition of each city into three rings discussed in earlier sections. Each city has a proportion of 1:3:6 for the radii of the three rings as illustrated in Fig. 11a. City size varies according to populations, using the six city types specified in Table 3. The ratio of ring 1 radii for the six city types to the radius of ring 1 for city type 6 follows:

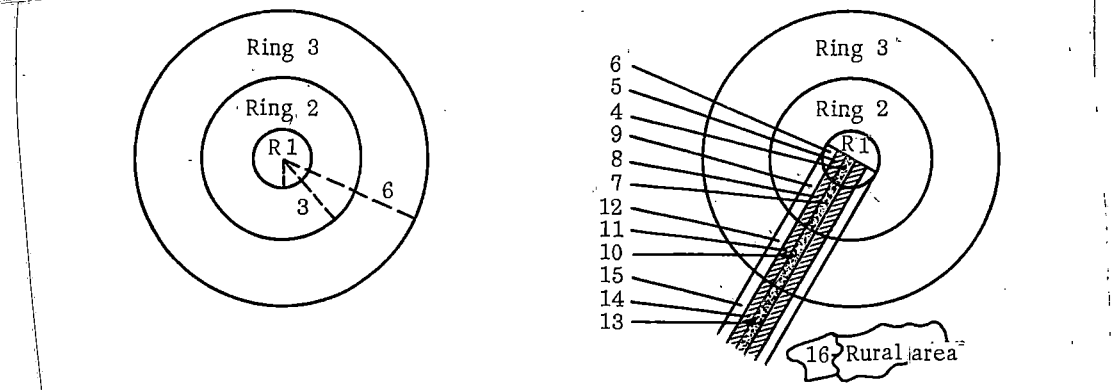
City Type	*City Ring Radius ÷ Type 6 City Ring Radius*
1	5.0
2	3.3
3	2.5
4	1.7
5	1.3
6	1.0

The third effect is a *rural area* effect, outside of the links and outside of cities. This captures residual effects in the rural area, which is the area in the region remaining after counting all links and cities.

The purpose of this partitioning is to appropriately locate and measure the distribution of the effects. Using this schematic, a total of 16 possible locations are identified, namely link-effects for each of the three link bands within each of the three city rings and in the rural area (a total of 12 locations), city-wide effects for each of the three rings, and the rural effect which is not link-associated. This partitioning is illustrated graphically in Fig. 11b.

A given transportation alternative may have all three of these types of effects on an individual societal attribute. Frequently,

*This assumption, of course, could be modified if the reasons for doing so were sufficiently compelling.



11a—City rings 11b—Link ring, and rural effects

Fig. 11--Partitioning of the region

however, there are citywide effects but no direct link-associated effects. This is usually the case for the attributes of personal income, industrial distribution, individual life style, community involvement, governmental form, tax policy, and government-supplied services. Also, an attribute may have neither link nor citywide effects. In this case, a regionwide assessment is made. This is done for the attributes electric power capacity and ecology. Methods for handling these various cases are described later in the discussion on worth estimation.

Continuing with our example, we use the 24 cities shown in Fig. 2, plus the rural area, denoted as another city--number 25--for purposes of computation. As mentioned, the 24 cities are divided into six types as defined in Table 3. The links also are divided into three types according to their traffic density--high, medium, or low. The portion of each link within a type 1 or 2 city is assigned a high density; within a type 3 or 4 city, a medium density; and within a type 5 or 6 city, a low density. The portion of each link outside the cities is assigned a medium density.

In order to relate worth values to different parts of the network and different time periods, we specify for each city and time period a *mode service combination* M'_{nt}, where n is the city (node) number and t is the time period. This shows the combination of modes serving

each city in each time period. In our example, we used 12 mode service combinations as follows:

Combination Number	*Modes*
1	Highway
2	Highway, Rail
3	Highway, Air[a]
4	Highway, Rail, Air
5	Highway, Air,[a] TACV
6	Highway, TACV
7	Highway, STOL
8	Highway, TACV, STOL
9	Highway, Air, Dual-Mode (DM)
10	Highway, DM
11	Highway, Rail, DM
12	Highway, Rail, Air, DM

[a]Air is conventional take-off and landing service (CTOL), but also includes the addition of STOL to existing CTOL service. For simplicity, it is assumed that the effect of this addition is minor.

In addition, for each set of mode links in a city, there is a *bandwidth* b'_{nt}, which sums over the area affected. The bandwidth expresses the total width, in hundreds of feet, of band 1 for all mode links. Figure 12 illustrates the bandwidth concept in a hypothetical city. Here the air mode has approximately two links of city radius length, the highway mode has three such links, and the dual-mode has

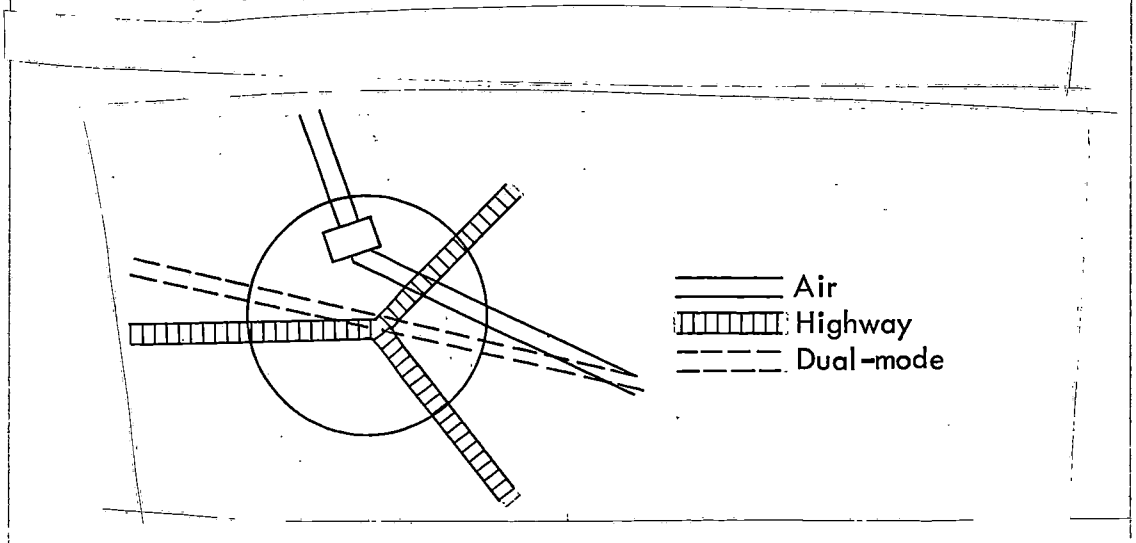


Fig. 12--Hypothetical city illustrating bandwidth computation for band 1

two links.* Therefore, the calculation of the bandwidth of band 1 for the modal service combination illustrated in Fig. 12 is 2 × 1 + 3 × 1 + 2 × .7 = 6.4 hundreds of feet. As indicated earlier, the width of band 2 is assumed to be four times the width of band 1, and the width of band 3 is seven times the band 1 width.

Table 55 shows the mode service combinations and the band 1 bandwidths, for each city n and each of the five-year time periods t, for the three mixes of modes.

Estimating Attribute Worth

Since we go to considerable length in this method to carefully sort out the societal impacts involved, it is worthwhile to begin the discussion on preparing worth estimates with a series of guidelines.

Worth values are to be assigned on a scale from 0 to +1.0 with the value representing the contribution toward achieving a given goal on that attribute for an individual, by the given mix of modes in a given regional segment. The values 0 and +1.0 have the following interpretation:

+1.0: The mix of modes contributes as much as any mix could conceivably contribute toward the attribute goal.

0: The mix of modes makes no contribution toward the attribute goal.

Values in between indicate the degree to which the goal is achieved.

Determining appropriate intermediate values may be facilitated by constructing a set of qualitative modifiers relating to each point along the scale. Such an adjective rating scale helps to insure consistency when moving among regional subsectors, from one attribute to another, and among different analysts preparing the estimates. Without such guidance, one may encounter a situation similar to the one we experienced in an early exercise when one researcher had in mind a scale which might be characterized roughly as .1-.3 for poor, .4-.6 for average, and .7-.9 for good, while another used an analog from

*Note that we have assumed all modes have separate routes into and out of the city.

Table 55

MODE SERVICE COMBINATIONS AND BANDWIDTHS FOR THE THREE MIXES OF MODES

City	1970-75 Mix 1		1970-75 Mix 2		1970-75 Mix 3		1975-80 Mix 1		1975-80 Mix 2		1975-80 Mix 3		1980-85 Mix 1		1980-85 Mix 2		1980-85 Mix 3	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1	4	5	4	5	4	5	4	5	4	5	4	5	4	5	5	5	12	5.7
2	2	4	2	4	2	4	2	4	2	4	2	4	2	4	6	4	11	5.3
3	2	4	2	4	2	4	2	4	2	4	2	4	2	4	6	4	11	5.3
4	4	9	4	9	4	9	4	9	4	9	4	9	4	9	5	8	12	10.3
5	2	4	2	4	2	4	2	4	2	4	2	4	2	4	6	4	11	5.3
6	4	8	4	8	4	8	4	8	4	8	4	8	4	8	5	8	12	9.3
7	4	5	4	5	4	5	4	5	4	5	4	5	4	5	5	5	12	5.7
8	1	3	1	3	1	3	1	3	1	3	1	3	1	3	1	3	1	3
9	1	3	1	3	1	3	1	3	1	3	1	3	1	3	1	3	1	3
10	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
11	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
12	4	7	4	7	4	7	4	7	4	7	4	7	4	7	3	6	4	7
13	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
14	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
15	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
16	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
17	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
18	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
19	2	4	2	4	2	4	2	4	2	4	2	4	2	4	1	2	2	4
20	2	6	2	6	2	6	2	6	2	6	2	6	2	6	1	4	2	6
21	2	4	2	4	2	4	2	4	2	4	2	4	2	4	1	2	2	4
22	1	4	1	4	1	4	1	4	1	4	1	4	1	4	1	4	1	4
23	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
24	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
25[a]	2	2	2	2	2	2	2	2	2	2	2	2	2	2	6	2.2	10	2.1

City	1985-90 Mix 1		1985-90 Mix 2		1985-90 Mix 3		1990-95 Mix 1		1990-95 Mix 2		1990-95 Mix 3		1995-2000 Mix 1		1995-2000 Mix 2		1995-2000 Mix 3	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1	4	5	5	5	12	5.7	4	5	5	6	12	6.3	4	5	5	6	12	6.3
2	2	4	6	4	11	5.3	2	4	6	4	11	5.3	2	4	6	4	11	5.3
3	2	4	6	4	11	5.3	2	4	6	4	11	5.3	2	4	6	4	11	5.3
4	4	9	5	10	11	11.6	4	9	5	10	11	11.6	4	9	5	10	11	11.6
5	2	4	6	4	11	5.3	2	4	6	4	11	5.3	2	4	6	4	11	5.3
6	4	8	5	9	12	10.0	4	8	5	10	12	10.6	4	8	5	10	12	10.6
7	4	5	5	5	12	5.7	4	5	5	6	12	6.3	4	5	5	6	12	6.3
8	1	3	1	3	1	3	1	3	7	6	10	5.0	1	3	7	6	10	5.0
9	1	3	1	3	1	3	1	3	7	6	10	5.0	1	3	7	6	10	5.0
10	1	2	1	2	1	2	1	2	7	4	10	3.3	1	2	7	4	10	3.3
11	1	2	1	2	1	2	1	2	7	4	10	3.3	1	2	7	4	10	3.3
12	4	7	5	8	12	8.3	4	7	5	10	12	9.6	4	7	5	10	12	9.6
13	1	2	1	2	1	2	1	2	7	4	10	3.3	1	2	7	4	10	3.3
14	1	2	1	2	1	2	1	2	7	4	10	3.3	1	2	7	4	10	3.3
15	1	4	7	5	10	4.7	1	4	8	8	10	6.6	1	4	8	8	10	6.6
16	1	2	1	2	1	2	1	2	7	4	10	3.3	1	2	7	4	10	3.3
17	1	2	1	2	1	2	1	2	7	4	10	3.3	1	2	7	4	10	3.3
18	1	2	7	2	10	3.3	1	2	6	4	10	3.3	1	2	6	4	10	3.3
19	2	4	6	4	11	5.3	2	4	6	4	11	5.3	2	4	6	4	11	5.3
20	2	6	6	6	11	7.3	2	6	8	8	11	8.6	2	6	8	8	11	8.6
21	2	4	6	4	11	5.3	2	4	6	4	11	5.3	2	4	6	4	11	5.3
22	1	4	7	6	10	5.3	1	4	8	8	10	6.6	1	4	8	8	10	6.6
23	1	2	7	4	10	3.3	1	2	6	4	10	3.3	1	2	6	4	10	3.3
24	1	2	1	2	1	2	1	2	7	4	10	3.3	1	2	7	4	10	3.3
25[a]	2	2	6	2.4	10	2.3	2	2	6	3	10	2.7	2	2	6	3	10	2.7

NOTE: Column 1 = mode service combination number; column 2 = bandwith for band 1 in hundreds of feet.

[a]Average values are used for links in rural areas.

the academic grading system assigning a value of .6 to poor, .7-.8 to average, and .9 to good. More extensive qualitative modifiers are also useful in many instances.

Recognize that in preparing estimates on a 0 to +1.0 scale, that higher positive values are always better, i.e., the alternative does a better job of achieving the attribute goal. Hence, in the case of attributes customarily having a negative interpretation, for example, air pollution, *less* pollution is better and would be assigned a higher value.

We will say a bit more about attribute goals shortly. First, however, we should emphasize the concept that the worth values which are assigned should be oriented toward an individual member of society. One can think of values as representing the *annual effect per individual.* In assigning values to the impact of the transportation alternative, neither the number of individuals affected nor the importance of the attribute in relation to other attributes is to be considered. The value is to reflect only how the alternative will impact on an individual in terms of the attribute being assessed.

In attempting to prepare these worth estimates, we found that some attributes usually--but not always--had a positive interpretation and some usually had a negative interpretation. For others, the interpretation was unclear because moving in one direction was better within certain ranges, or for some individuals, or if some objectives were desired, while the other direction was to be preferred if other ranges, individuals, or objectives were involved. To clarify this point, we found it helpful to set up brief, one-sentence goals for each of the attributes. Our purpose was to establish a skeletal framework of societal goals against which to assess the alternatives--and more particularly, to make explicit the direction which was to be preferred in this example for each attribute.

One other point should be mentioned about the 0 to +1.0 scales. Remember that +1.0 represents the "maximum that any mix could conceivably contribute toward the attribute goal." The interpretation was phrased in this fashion to recognize that in most instances regional development or other societal goals are not achieved wholly or even

primarily by transportation improvements. In some later study of possible regional futures it may well be desirable to assess transportation as well as other regional development alternatives with regard to how well they would do in an absolute sense in achieving an attribute goal.* At this point, however, we are limiting ourselves to a comparison of transportation alternatives, so it appears more fruitful to prepare worth values which rank the individual alternatives in relation to the best conceivable transportation improvements. The one sentence goals which we developed for each of the 22 societal attributes in this exercise are as follows:

1. *Human Physiology. Air Pollution:* Reduce to a level acceptable to practically all people. *Noise:* Reduce to a level acceptable to practically all people. *Accidents to non-users:* Reduce to a bare minimum accidents and fear of accidents for non-users.
2. *Right-of-Way Associated. Partitioning:* Avoid partitioning of communities, especially in densely populated areas. *Displacement:* Reduce displacement of residences and industries by transportation to a level that is equal to the displacement by other causes. *Construction inconvenience:* Reduce inconvenience of transportation construction to a level equal to the inconvenience from other causes--e.g., laying gas or sewer pipes or cables, or repairing these. *Property values:* Avoid rapid changes in property values, either as a direct result of transportation changes (from right-of-way purchase) or as an indirect result (from development of new business and residential districts).
3. *Economic. Employment:* Increase opportunities for employment, especially in high unemployment neighborhoods. *Personal income:* Aid the low income group to increase its income relative

*In such a future exercise it also would be interesting and potentially useful to develop each attribute goal in considerably more detail, as well as to specify more concretely possible physical measures which might be used in assessing the extent to which these goals are achieved.

to other groups by creating employment opportunities in low income areas. *Industrial distribution:* Restore a "balance of industry" by directing new industry into rings 1 and 3. *Population distribution:* Provide the opportunity for population to relocate from crowded to less crowded cities or other areas.

4. *Metropolitan Form and Design. Land use distribution:* Create an equitable division of land area among residential, commercial, industrial, agricultural, park and recreation, and other public and institutional uses. Also create a harmonious locational blend of these uses. *Housing:* Create an adequate supply of housing within the budget of each income group. *Design:* Maintain an aesthetically pleasing and efficient design of the transportation structures, of buildings near the transportation lines and terminals, and of the city layout.
5. *Sociological-Political. Individual life style:* Provide ample leisure time for the individual and the opportunity to do a variety of things in that time. *Community involvement and communication:* Facilitate the participation by individuals in community affairs, and their interaction with neighbors. *Government form and intergovernmental relations:* Increase the degree of cooperation among different levels of government with each maintaining an appropriate division of responsibility. Maintain responsiveness of government units to the people. *Tax policy:* Strengthen the community tax base and decrease the cost of government-supplied services. Also make the incidence of construction costs on the population equitable. *Government-supplied services:* Increase the quantity and quality of services such as police, fire control, refuse disposal, and education.
6. *Scarce Resources. Radio reception:* Maintain good quality radio reception near electrified links and throughout the region. *Electric power capacity:* Maintain capacity sufficient that an electrified transportation system does not black out other uses. Minimize adverse environmental effects from

building this capacity. *Ecology:* Maintain a balance of life forms and climatic conditions; minimize adverse technological effects on this balance.

To ensure that all effects are assessed but that there is no double counting, the following guidelines are used. For attributes in which there are link, citywide and rural effects, worth values assigned to link bands are determined so as to include citywide effects associated with the ring in which the band is located as well as the peculiarly link-associated effects. Also, link effects in rural areas are to include rural areawide effects within the link bands.

For attributes in which no peculiarly link-associated effects are involved, values assigned to the three city rings are also to be shown for each link band included within the rings. Likewise, for links in rural areas, the rural worth numbers are to be applied to link bands within the rural area as well as to the rural area in general.

For attributes in which only region-wide effects are identified, the worth value is to be assigned to all regional subsections.

The actual process of preparing the worth estimates is systematized by completing a worksheet on each attribute, as illustrated in Table 56 for the attribute *Property Values*. These worksheets reflect the dimensions that we considered most significant, with the columns showing different mode service combinations and the rows showing variation by link density, link band, city type, city ring, and rural. Variation over time of the mix of modes serving a given city is captured through the mode service number and bandwidth inputs in Table 55.

In this illustration where the goal was to avoid rapid changes in property values as either a direct or indirect result of transportation changes, we expected all mode service combinations to do relatively poorly in terms of link effects, particularly in bands 1 and 2, and to have relatively modest impacts citywide. Also, although the absolute dollar impact on property values would undoubtedly be greater in larger cities, the relative (percentage) change probably would not; therefore, the numbers assigned show insensitivity among city sizes. Some sensitivity to link traffic density probably should have been shown to reflect differences in the congestion and commerce introduced;

Table 56

WORTH ESTIMATION PROCEDURE: WORTHS FOR THE PROPERTY VALUES ATTRIBUTE

Item	*Mode Service Combination* 1	2	3	4	5	6	7	8	9	10	11	12
Link effect												
High density												
Band 1	.2	.1	.2	.1	.1	.1	.2	.05	.1	.1	.05	.05
Band 2	.5	.4	.5	.4	.4	.4	.5	.4	.4	.4	.3	.2
Band 3	.7	.6	.7	.6	.6	.6	.7	.6	.6	.6	.5	.4
Medium density												
Band 1	.2	.1	.2	.1	.1	.1	.2	.05	.1	.1	.05	.05
Band 2	.5	.4	.5	.4	.4	.4	.5	.4	.4	.4	.3	.2
Band 3	.7	.6	.7	.6	.6	.6	.7	.6	.6	.6	.5	.4
Low density												
Band 1	.2	.1	.2	.1	.1	.1	.2	.05	.1	.1	.05	.05
Band 2	.5	.4	.5	.4	.4	.4	.5	.4	.4	.4	.3	.2
Band 3	.7	.6	.7	.6	.6	.6	.7	.6	.6	.6	.5	.4
Citywide effect												
City-type 1												
Ring 1	.8	.7	.8	.7	.7	.7	.7	.6	.7	.7	.6	.6
Ring 2	.8	.7	.5	.5	.5	.7	.8	.7	.5	.7	.6	.4
Ring 3	.8	.7	.8	.7	.7	.7	.8	.7	.7	.7	.6	.6
City-type 2												
Ring 1	.8	.7	.8	.7	.7	.7	.7	.6	.7	.7	.6	.6
Ring 2	.8	.7	.5	.5	.5	.7	.8	.7	.5	.7	.6	.4
Ring 3	.8	.7	.8	.7	.7	.7	.8	.7	.7	.7	.6	.6
City-type 3												
Ring 1	.8	.7	.8	.7	.7	.7	.7	.6	.7	.7	.6	.6
Ring 2	.8	.7	.5	.5	.5	.7	.8	.7	.5	.7	.6	.4
Ring 3	.8	.7	.8	.7	.7	.7	.8	.7	.7	.7	.6	.6
City-type 4												
Ring 1	.8	.7	.8	.7	.7	.7	.7	.6	.7	.7	.6	.6
Ring 2	.8	.7	.5	.5	.5	.7	.8	.7	.5	.7	.6	.4
Ring 3	.8	.7	.8	.7	.7	.7	.8	.7	.7	.7	.6	.6
City-type 5												
Ring 1	.8	.7	.8	.7	.7	.7	.7	.6	.7	.7	.6	.6
Ring 2	.8	.7	.5	.5	.5	.7	.8	.7	.5	.7	.6	.4
Ring 3	.8	.7	.8	.7	.7	.7	.8	.7	.7	.7	.6	.6
City-type 6												
Ring 1	.8	.7	.8	.7	.7	.7	.7	.6	.7	.7	.6	.6
Ring 2	.8	.7	.5	.5	.5	.7	.8	.7	.5	.7	.6	.4
Ring 3	.8	.7	.8	.7	.7	.7	.8	.7	.7	.7	.6	.6
Rural effect	.5	.4	1.0	.4	.4	.4	1.0	.4	.4	.4	.3	.2

however, these would be modest because the same amount of land is assumed to be consumed by the links regardless of the density. An expanded set of assumptions of this sort is generated in the analyst's

mind during the process of preparing these worth estimation worksheets. It is desirable to document these assumptions briefly as supporting detail for the worksheets.

The information provided in Table 56 is denoted in the following fashion. The notation $E^{'CL}_{aM'db}$ is used to define link effects within a city, where $E^{'CL}_{a}$ is the worth per individual for a given attribute, M' is the mode service combination number, d is the link traffic density, and b is the link band. Notation for rural links is the same except $E^{'RL}_{a}$ is substituted for $E^{'CL}_{a}$. Citywide effects are denoted $E^{'CNL}_{aM'n'r}$ where $E^{'CNL}_{a}$ is the worth per individual for the attribute, n' is the city type and r is the city ring. Rural non-link effects are specified $E^{'RNL}_{aM'}$.

Calculating Incidence

Having completed the worth estimation portion of the procedure, we turn now to the calculation of incidence, that is, the number of people affected in each spatial partition. This is obtained by computing the fraction of the population in each location and multiplying these fractions by the total population of the city or the rural area.

The populations of the cities and the rural area, estimated at mid-period for each of our six time periods, and for both Regional Environments A and B were provided in Table 9. These data may be denoted symbolically as P_{nt}, e.g., population of city n in time period t.

The populations must be apportioned among *link*, *citywide*, and *rural* effects. The fraction of the population of each city in a 100-ft wide *link* band is readily obtainable from the city geometry, and from the ring residential population percentages in Table 57. These fractions are given by city size and ring in Table 57. When multiplied by the appropriate bandwidth for any given city and time period, they give the population fraction in band 1. As implied earlier, band 2 and 3 fractions are obtained by multiplying band 1 by 4 and 7, respectively. If desired, these fractions may be further divided by income group, using the percentages presented earlier in Table 7. The result is denoted symbolically as $p^{CL}_{brgn'}$, or the fraction of a city population

Table 57

FRACTION OF POPULATION IN A 100-FT WIDE LINK BAND IN A CITY

City	*Ring 1*	*Ring 2*	*Ring 3*
1	.00044	.000105	.0000386
2	.00066	.000157	.0000579
3	.00088	.000209	.0000772
4	.00132	.000314	.0001157
5	.00165	.000392	.0001446
6	.00220	.000522	.0001929

involved in city link effects in band b, ring r, income group g, and city type n'.

The fraction of people involved in *rural link* effects is obtained by finding how much area each band along the rural mileage will consume, relative to the total rural area in the region. This gives us p_{bg}^{RL}, or the fraction of rural population involved in link effects by band b and income group g. The total fraction consumed by all three link bands was .0048.

The fraction of people *citywide, exclusive of link* effects, is found by subtracting the link-associated population fraction given in Table 57 from the total city population fraction in each ring. Letting the total city population fraction be p_{rg}^{C}, we subtract the link effect population fraction as follows:

$$p_{rgn'}^{CNL} = p_{rg}^{C} - \sum_{b=1}^{3} p_{brgn'}^{CL} \qquad (13)$$

Finally, the fraction of people experiencing *rural non-link* effects is the remainder after subtracting the rural link effect fraction--namely, .9952 of the rural population. This gives p_{g}^{RNL}, the fraction of rural population involved in non-link effects by income group g. The breakout by income group in the rural area is assumed to be the same as that for ring 3.

The number of people involved in these various effects, for city n in time period t, can be summarized as follows, when n' is the city

type, b' is the band 1 bandwidth multiplier, and b'' is the band number factor, i.e., 1, 4, or 7 for bands 1, 2, or 3. For *link effects within the cities* (cities numbered 1 through 24), the number of people Q^{CL}_{brg} in band b, ring r, and income group g is the product of the city population P^C, the fraction of people per 100-ft width of band 1, the bandwidth b', and the band number factor b''. Hence,

$$Q^{CL}_{ntbrg} = P^C_{nt} \cdot p^{CL}_{b} 100 ft_{rgn'} \cdot b' \cdot b'' \quad . \tag{14}$$

For the *link effects in rural* areas (inputted as city number 25), the number of people, Q^{RL}_{brg}, in band b and income group g is the product of the rural population, the fraction of rural people per 100-ft width of band 1, and the bandwidth b' and the band number factor b'':

$$Q^{RL}_{ntbrg} = P^C_{nt} \cdot p^{RL}_{b} 100 ft_{g} \cdot b' \cdot b'' \quad . \tag{15}$$

For the *citywide non-link effects* (n = 1 through 24), the number of people, Q^{CNL}_{rg}, in ring r and income group g is the product of the city population P^C with the fraction of people in each ring and income group, minus the people already counted in all the links. Using Eq. (13),

$$Q^{CNL}_{ntrg} = P^C_{nt} \cdot p^{CNL}_{rgn'} \quad . \tag{16}$$

For the *rural effects* (n = 25), the number of people in income group g is the product of the rural population P^C and the fraction involved in rural non-link effects:

$$Q^{RNL}_{ntg} = P^C_{nt} \cdot p^{RNL}_{g} \quad . \tag{17}$$

Computing Aggregate Weighted Worth

The aggregate worth for each attribute is obtained by multiplying each worth estimate by its corresponding incidence--i.e., number of

people affected--and summing over bands b, rings r, and cities n as follows:

$$E^{CL}_{agt'} = \sum_{brn} \left[E'^{CL}_{aM'db} \cdot Q^{CL}_{ntbrg} \right] \tag{18}$$

$$E^{RL}_{agt'} = \sum_{brn} \left[E'^{RL}_{aM'db} \cdot Q^{RL}_{ntbrg} \right] \tag{19}$$

$$E^{CNL}_{agt'} = \sum_{rn} \left[E'^{CNL}_{aM'n'r} \cdot Q^{CNL}_{ntrg} \right] \tag{20}$$

$$E^{RNL}_{agt'} = \sum_{n} \left[E'^{RNL}_{aM'} \cdot Q^{RNL}_{ntg} \right] \tag{21}$$

These effects may be combined into a single aggregate worth, $E_{agt'}$, for the attribute by income group by summing over city link (CL), rural link (RL), city non-link (CNL), and rural non-link (RNL) values. The notation t' indicates that these values have a connotation of *annual* worth.

Another multiplication is needed before summing over the attributes, namely, by an appropriate weight for each attribute. An average of several analysts' subjective weightings, constructed using pairwise comparison techniques and with weights summing to 1000, is as follows:

Attribute	*Weight*
Air pollution	76
Noise	71
Accidents to non-users	87
Partitioning	26
Displacement	18
Construction inconvenience	18
Property values	18
Employment	92
Personal income	129
Industrial distribution	19
Population distribution	24
Land use distribution	41
Housing	21
Design	21
Individual life style	81
Community involvement	41

Attribute--continued	*Weight*
Government form	31
Tax policy	31
Government services	64
Radio reception	14
Electric power capacity	17
Ecology	60
Total	1000

These weights are designed to reflect the preferences of an *individual* in assessing the 22 societal attributes. For the purpose of simplicity in illustration, one set of weights was assumed for all the income groups.

Table 58 provides a sample output from the computer program that executed this spatially-oriented example. This table shows five-year aggregate worths in millions summed over income groups for the 22 attributes and in time periods of Regional Environment A, Mix 1. Since the basic worth estimates in Table 56 are assumed to be annual worths, estimates have been multiplied by five to obtain the five-year aggregates. Hence,

$$B^V_{at} = \sum_g [E_{agt'} \cdot W_a \cdot 5] \qquad (22)$$

where B^V_{at} is the societal benefit by attribute and five-year time period and W_a is the attribute weight. Similar outputs for the other regional environments and mixes are given in the appendix as Table 66. These worth numbers or *benefit indices* may be analyzed in conjunction with the numbers produced in the user analysis. Table 59 presents summary statistics for all regional environments and mixes.

Aggregation by income group is possible but was not run on the computer at the time of this report. Information may also be summarized by city, city type, major attribute within city type, and so on. One supplementary analysis which was run to illustrate the potential of the methodology was the number of people affected at each worth level from 0 to +1.0 for the *Human Physiology* attributes. This output,

Table 58

ANALYSIS OF SOCIETAL BENEFITS
Regional Environment A, Mix 1

	Five-Year Benefit Indices					
	1970-75	1975-80	1980-85	1985-90	1990-95	1995-00
Human Physiology						
Air Pollution	12.2	13.2	14.2	15.3	16.5	17.9
Noise Pollution	7.5	8.1	8.8	9.5	10.2	11.0
Acc to Non-User	13.8	14.9	16.1	17.4	18.8	20.3
Subtotal:	33.5	36.2	39.0	42.2	45.6	49.1
Right-of-Way Associated						
Partitioning	1.2	1.3	1.4	1.5	1.6	1.7
Displacement	2.3	2.5	2.7	2.9	3.1	3.4
Constr Incon	2.2	2.4	2.6	2.8	3.0	3.2
Proprty Values	1.9	2.0	2.2	2.4	2.5	2.7
Subtotal:	7.5	8.1	8.8	9.5	10.2	11.1
Economic						
Employment	6.9	7.4	8.0	8.7	9.4	10.2
Personal Income	9.5	10.3	11.1	12.0	13.0	14.1
Indus Dist	1.6	1.7	1.9	2.0	2.2	2.4
Pop Dist	.4	.4	.5	.5	.5	.6
Subtotal:	18.3	19.8	21.5	23.3	25.1	27.2
Metropolitan Form and Design						
Land Use Dist	.7	.8	.9	.9	1.0	1.1
Housing	.0	.0	.0	.0	.0	.0
Metro Design	1.9	2.1	2.2	2.4	2.6	2.8
Subtotal:	2.7	2.9	3.1	3.3	3.6	3.9
Sociological-Political						
Ind Life Style	7.3	7.9	8.5	9.2	10.0	10.8
Commty Involvmt	4.0	4.3	4.7	5.0	5.4	5.9
Government Form	1.6	1.7	1.8	2.0	2.1	2.3
Tax Policy	1.0	1.0	1.1	1.2	1.3	1.4
Govt Services	3.3	3.6	3.7	4.0	4.3	4.7
Subtotal:	17.2	18.6	19.8	21.5	23.2	25.0
Scarce Resources						
Radio Reception	2.3	2.5	2.7	2.9	3.2	3.4
Elec Power Cap	2.6	2.8	3.0	3.3	3.6	3.8
Ecology	1.8	2.0	2.1	2.3	2.5	2.7
Subtotal:	6.8	7.3	7.9	8.5	9.2	10.0
GRAND TOTAL:	86.0	93.0	100.1	108.3	116.9	126.2

Table 59

ANALYSIS OF SOCIETAL BENEFITS

Five-Year Summary Benefit Indices

	1970-75	*1975-80*	*1980-85*	*1985-90*	*1990-95*	*1995-2000*
Environment A						
Mix 1	86.0	93.0	100.1	108.3	116.9	126.2
Mix 2	86.0	93.0	110.1	119.2	130.6	140.8
Mix 3	86.0	93.0	111.2	122.1	133.4	144.0
Environment B						
Mix 1	83.2	92.4	97.9	105.0	115.0	132.2
Mix 2	83.2	92.4	107.0	114.8	127.0	146.8
Mix 3	83.2	92.4	108.1	117.6	131.3	152.7

shown in Table 60, may also be viewed as a bar graph summing over all individuals in the region who are affected at each level of worth.* This distribution of effects by *intensity* should be useful in assessing public reaction. People near the zero level are very seriously affected by the alternative and may be expected to oppose it. The strength of such opposition and the attributes through which the effect is felt, may be evaluated for each alternative. Such information could be an important supplementary input to the decision process.

SUMMARY

Two comprehensive evaluation methods for societal benefits have been illustrated in this Section. Both methods generate the same general type of output, namely, weighted worth information aggregated over the region and over its inhabitants. In the second method, however, the results are generated far more carefully and a multiplicity of intermediate summaries is available. This information is useful in analyzing the relative magnitudes of various types of societal effects introduced by various transportation improvements and assuming alternative regional environments develop in the future. As indicated,

*Concentration of individuals at the .3, .7, and .8 levels for the *Noise* attribute are the result of the fact that worth values for city bands and rings are inputted as point estimates rather than functions.

Table 60

ANALYSIS OF SOCIETAL BENEFITS
Regional Environment A, Mix 1
Population Affected by Intensity of Effect

(In millions)

	1970-75	1975-80	1980-85	1985-90	1990-95	1995-00
Human Physiology						
Air Pollution						
1.0	21.93	23.68	25.49	27.55	29.71	32.02
.9	9.63	10.44	11.31	12.27	13.29	14.39
.8	.07	.07	.09	.09	.10	.11
.7	.01	.02	.02	.02	.02	.03
.6	.00	.00	.00	.00	.00	.00
.5	.00	.00	.00	.00	.00	.00
.4	.00	.00	.00	.00	.00	.00
.3	.00	.00	.00	.00	.00	.00
.2	.00	.00	.00	.00	.00	.00
.1	.00	.00	.00	.00	.00	.00
.0	.00	.00	.00	.00	.00	.00
Noise Pollution						
1.0	4.08	4.35	4.57	4.87	5.14	5.42
.9	.02	.02	.02	.02	.02	.02
.8	7.97	8.63	9.32	10.11	10.95	11.86
.7	9.95	10.77	11.70	12.69	13.75	14.89
.6	.01	.01	.01	.01	.01	.01
.5	.04	.04	.03	.03	.03	.04
.4	.06	.06	.08	.09	.10	.10
.3	9.50	10.29	11.15	12.08	13.09	14.18
.2	.01	.01	.01	.01	.01	.01
.1	.01	.02	.02	.02	.02	.03
.0	.00	.00	.00	.00	.00	.00
Acc to Non-User						
1.0	31.62	34.17	36.88	39.90	43.10	46.52
.9	.02	.03	.03	.03	.03	.03
.8	.00	.00	.00	.00	.00	.00
.7	.00	.00	.00	.00	.00	.00
.6	.00	.00	.00	.00	.00	.00
.5	.00	.00	.00	.00	.00	.00
.4	.00	.00	.00	.00	.00	.00
.3	.00	.00	.00	.00	.00	.00
.2	.00	.00	.00	.00	.00	.00
.1	.00	.00	.00	.00	.00	.00
.0	.00	.00	.00	.00	.00	.00

the information is of particular relevance when combined with user and operator information for a complete summary evaluation of transportation alternatives.

VII. A COMPREHENSIVE EXAMPLE INCLUDING SENSITIVITY ANALYSES

INTRODUCTION

To this point, we have developed information on the user and societal benefits associated with each alternative mix of transportation modes when introduced into each regional environment. We now are in a position to combine this into a complete example. The purpose of this section is to summarize the information and show how it contributes toward making a decision among the proposed alternatives.

First, we present a summary of the incremental benefits of the improved mixes of modes over the base mix, by attribute and time period. Then we discuss a comparison of the alternatives on the basis of this benefit information, assuming implicitly that the alternatives are of equal cost: Comparisons are made of the benefits of each of the two improved mixes in a given regional environment, and of a given improved mix assuming each of the two regional environments were to occur. Next, we suggest a variety of supplementary analyses emphasizing presentation of benefits by income group, mode and city size among others. We conclude with a discussion on incorporating this summary benefit information with cost information and policy options in making a decision.*

A SUMMARY OF INCREMENTAL BENEFITS

In Section III and in the spatially-oriented example of Section VI, we developed benefit indices for user and societal attributes, for each mix of modes in each time period and in each regional environment. These numbers become particularly relevant when the *differences* between pairs of alternatives are compared. Specifically, we can compare each mix of modes containing improved transportation facilities (i.e., the TACV/STOL mix and the Dual-Mode mix) with the base mix. The incremental benefit of each of these mixes over the base mix has been obtained at an increment of cost, which we shall discuss briefly later. The

*Further discussion of the methodology illustrated in this section is provided in Section VIII of Volume II, Ref. 1.

decisionmaker must decide which improved mix represents the best investment--i.e., provides the most incremental benefits--for its incremental cost.

A basic summary of benefit is illustrated in Table 60. It shows the incremental benefit of the TACV/STOL mix over the base mix in Regional Environment A by major attribute, and for six 5-year time periods.* The user benefit for the line-haul part of the trip, by major attribute, is computed from the results illustrated in Table 19. Added to these, are estimates of the incremental benefit from access and egress portions of the trip.†

The operators are handled in this example as a constraint. That is, we assume that certain criteria are satisfied for each operator attribute for each alternative. These criteria, stated for the major attributes, are that the operators receive a 10 percent long-term return on their investment, that they have long-term franchises, and that excessive regulatory control is avoided.‡

The incremental societal benefit is computed from the information provided in Table 66 in the appendix. However, the user and the societal benefit indices do not have the same interpretation and in their current form should not be added together. The user worth is the sum of worths on individual trips, expressed in passenger miles, and the societal worth is the sum of worths per year over individuals residing in the region. If one wishes to derive a grand total of the user and societal benefits, relative weightings of the user and the societal worth scores are necessary. To develop these we need to ask explicit questions that compare the worth from user attributes with the worth

*There are no incremental benefits in the first two time periods since the new modes do not start service until 1980. A possible exception is benefits and disbenefits associated with construction, but these are not identified here.

†Also included is a factor entitled "excess of Post-Trip Benefits." This line item is intended to account for the benefits which are derived upon the completion of trips. Pleasure in visiting relatives or profit from making a sale during a business trip, exceed the disbenefits--in time and cost expended, inconvenience experienced, etc.--associated with making the trip. This item was calculated using a factor based on approximate calculations of consumer surplus. Its inclusion makes the overall budget computation more complete conceptually, but it is not essential for the analysis.

‡The reason behind these assumptions is discussed in Secs. III and IV of Volume II and in Section VI of Ref. 5.

Table 60

INCREMENTAL BENEFIT OF MIX 2 (TACV/STOL) OVER MIX 1 (BASE MIX) IN REGIONAL ENVIRONMENT A

	5-Year Benefit Indices						
Attributes	*1970-1975*	*1975-1980*	*1980-1985*	*1985-1990*	*1990-1995*	*1995-2000*	*Total*
Users							
Line-haul							
Travel time			19	23	27	30	99
Travel cost			14	16	19	21	70
Convenience			14	16	19	21	70
Safety & security			19	23	27	30	99
Comfort			26	30	36	40	132
Subtotal			92	108	128	142	470
Access-egress			74	86	102	114	376
Excess of post-trip benefits			28	33	39	44	144
Total			194	227	269	300	990
Operators[a]							
Profitability							
Survivability							
Flexibility							
Society							
Human physiology			0	.1	.2	.3	.6
Right-of-way-associated			0	0	0	-.1	-.1
Economic			.2	.3	.5	.4	1.4
Metropolitan form & design			.8	1.0	1.2	1.3	4.3
Sociological-political			1.1	1.3	1.6	1.7	5.7
Scarce resources			.7	.5	1.5	1.5	4.2
Total			2.8	3.2	5.0	5.1	16.1

[a] Operator attributes are treated as constraints. We assume for profitability a 10 percent long-term return on investment, for survivability a long-term franchise, contingent on continued provision of reasonably efficient service, and for flexibility the avoidance of excessive regulatory control.

from societal attributes. Specifically let us compare the *cost* of a New York to Washington trip by a middle-income person traveling on business, with a year's worth of *noise pollution* caused by airplanes going over his house. We estimated in Section IV through a willingness to pay or indifference exercise that one user worth unit can be viewed as roughly equivalent to $50. Extending this reasoning, we could take

any user worth score and estimate the equivalent dollar value.* In Section V, we illustrated that airplanes passing at a peak intermittent noise level of 100-105 PNdB cause a worth level of 0.5, which is a decrement of 0.5 from the ideal of 1.0. Suffering this for one year is equivalent, let us say, to a loss of $200. This estimate also is developed using a series of questions designed to elicit willingness-to-pay information. Applying the weight of 71 given to noise in Section VI (taken as .071 in computing Table 61) gives weighted worth (.5)(.071) = .0355. Hence, $200 is equivalent to .0355 worth units on the societal worth scale and we can derive a means of equating user and societal weighted worths as follows

$$\frac{1}{.0355} \cdot \frac{200}{50} = 112.$$

This process may be repeated using several different societal attributes if desired to "fine tune" the numbers, and the results averaged. The comparison may be performed by analysts, by decisionmakers, or using a survey sampling members of the population experienced with both user and societal attributes. The resulting weight, assuming it is 112, may be used to multiply each of the societal scores appearing in Table 60, and then it is appropriate to add user and societal worths. Of course, such grand total weighted worths are only one of several inputs to a selection among alternatives. The user and societal subtotals as well as many of the supporting details, especially regarding distributions of the benefits, are probably more valuable than the single aggregate.

We turn now to the question of totalling benefits over time. In the right-hand column of Table 60 the incremental benefits anticipated in the six time periods are added. No discounting assumption has been incorporated, or stated alternatively, the totals may be viewed as present values of the incremental benefit at a discount rate of zero. It is not clear what rate of discount should be used for benefits. The

*If the worth scores have been correctly calibrated, the conversion factor should be the same for any attribute chosen.

concept of trading benefits now for benefits later does not have exactly the same interpretation as the similar concept of cost, because it is not clear that all types of benefits can be foregone now in the hope of larger returns in the future.* The summation in Table 60 does have practical appeal as a way of condensing the time phased information. Explicit discounting assumptions may be introduced later if desired. The determination of appropriate rates is really a subject for separate study.

Three additional basic summary tables like Table 60 could be constructed--for the Dual-Mode mix over the base mix in Regional Environment A, and for the two improved mixes assuming Regional Environment B. These summaries provide the information for a comparison of alternatives.

THE COMPARISON OF ALTERNATIVES

For each regional environment, we can compare the performance of the different mixes of modes. This gives us a feeling about how the benefit would change if our mode decision changed. The first three columns of Table 61 show this comparison for the Dual-Mode mix versus the TACV/STOL mix for Regional Environment A, with societal worth scores multiplied by 112 as just discussed. The first column is the incremental benefit of the TACV/STOL mix over the base mix, as shown in Table 60. The second column presents the same information for the Dual-Mode mix over the base mix. The third column is the difference. The third column suggests that the Dual-Mode mix is superior to the TACV/STOL mix for Regional Environment A, in both user and societal totals.† The salient differences by major attribute are displayed. A similar comparison could be made for Regional Environment B.

Similarly, for each mode mix we can compare its performance in the two regional environments. This gives us a feeling about how the benefits would change if the regional environment developed in alternative

*This issue is discussed in Section IX of Ref. 5.

†We should emphasize that all findings in this section are illustrative and therefore should be viewed as hypothetical.

Table 61

COMPARING THE INCREMENTAL BENEFITS OF NEW MODE MIXES, 1970-2000

Item	Regional Environment A			Regional Environments A and B			
	Mix 2 - Mix 1 (TACV/STOL Added)	Mix 3 - Mix 1 (Dual-Mode Added)	Mix 3 - Mix 2 (Difference)	Mix 2 - Mix 1 (TACV/STOL Added)		Mix 3 - Mix 1 (Dual-Mode Added)	
				Reg. Env. A	Reg. Env. B	Reg. Env. A	Reg. Env. B
User							
Line-haul							
Travel time	99	116	17	99	134	116	144
Travel cost	70	113	43	70	90	113	103
Convenience	70	195	125	70	154	195	219
Safety and security	99	151	52	99	138	151	168
Comfort	132	161	29	132	78	161	181
Subtotal	470	736	266	470	594	736	815
Access-egress	376	589	213	376	476	589	652
Excess of post trip benefits	144	225	81	144	182	225	249
Total	990	1550	560	990	1252	1550	1716
Operators[a]							
Profitability							
Survivability							
Flexibility							
Society							
Human physiology	68	661	593	68	-213	661	605
Right-of-way associated	-11	-672	-661	-11	-78	-672	-672
Economic	138	- 56	-194	138	101	- 56	- 67
Metropolitan form & design	485	270	-215	485	314	270	302
Sociological-political	642	1712	1070	642	683	1712	1759
Scarce resources	473	493	20	473	616	493	616
Total	1795	2408	613	1795	1423	2408	2543
Grand total	2785	3958	1173	2785	2675	3958	4259

[a] Operator attributes are treated as constraints. We assume for profitability a 10 percent long-term return on investment, for survivability a long-term franchise, contingent on continued provision of reasonably efficient service, and for flexibility the avoidance of excessive regulatory control.

ways as time passed. The last four columns of Table 61 show this comparison for each new mode mix, again using 1970-2000 totals. The first two of these columns compare the incremental benefits of the TACV/STOL mix over the base mix, assuming each regional environment. The last two columns do the same for the Dual-Mode mix. Regional Environment B results in higher incremental user totals for both mixes than Regional Environment A, but in a lower incremental societal total for the TACV/STOL mix. Again the salient differences are displayed by major attributes.

ADDITIONAL USEFUL ANALYSES OF THE BENEFITS

There are many possible displays of the benefits other than by major attribute. It is important, for example, to show user and societal benefits by income group. Division of user benefits by mode and of societal benefits by city size also are particularly useful.

Table 62 displays line-haul user benefits by mode and by income group. The breakout by mode shows the impact of the new modes on existing modes. The division by income group shows how the benefits are distributed among these groups. The poverty group receives practically no benefit because of low travel propensity, and the upper income group receives more than its proportionate share because of high travel propensity.

Table 63 presents two illustrative divisions of the societal benefits. The first is a division by income group, showing how societal benefits are distributed in relation to the group percentages of the population. This is followed by a division by city size, showing how benefits are distributed to the residents of various city sizes, in relation to their percentage of the population.

In connection with the division of benefit by income group, another point can be made. There is no inherent reason to simply add the benefits of these different groups, except each person has one vote--other methods are subject to challenge. It is possible, at the risk of argument, to assign weights other than 1 to the different group benefits. For example, it may be desirable for policy reasons to assign a larger weight to the poverty group than to other groups. This might be done so as to avoid the problem of designing only for the majority as often

Table 62

ANALYSIS OF INCREMENTAL LINE-HAUL USER BENEFIT IN REGIONAL ENVIRONMENT A, 1970-2000

Item	*Mix 2 - Mix 1 (TACV/STOL Added)*	*Mix 3 - Mix 1 (Dual-Mode Added)*	*Mix 3 - Mix 2 (Difference)*
Mode			
Auto	-143	-491	-348
Bus	- 11	0	11
Rail	-323	-128	195
Air	-195	-134	61
TACV	1095		-1095
STOL	47		- 47
Dual-Mode		1489	1489
	470	736	266
Income group			
Poverty, < $4K	0	6	6
Lower, ≥ $4 < 10K	64	122	58
Middle, ≥ $10 < 20K	319	485	165
Upper, ≥ $20K	87	123	37
	470	736	266

Table 63

COMPARING SOCIETAL BENEFITS OF MIX 2 (TACV/STOL ADDED) VERSUS MIX 3 (DUAL-MODE ADDED) IN REGIONAL ENVIRONMENT A, 1970-2000

	Percent Total Pop.		*Mix 2 - Mix 1 (TACV/STOL Added)*		*Mix 3 - Mix 1 (Dual-Mode Added)*		*Mix 3 - Mix 2 (Difference)*	
Item	*1970*	*2000*[a]	*Benefits*	*%*	*Benefits*	*%*	*Benefits*	*%*
Income Group								
Poverty, $ < 4K	10	10	108	6	192	8	84	14
Lower, ≥ $4 < 10K	50	50	754	42	1108	46	354	58
Middle, ≥ $10 < 20K	32	32	718	40	867	36	149	24
Upper, ≥ $20K	8	8	215	12	241	10	26	4
Total	100	100	1795	100	2408	100	613	100
City Size								
> 10 million	52.9	52.1	952	53	1276	53	324	53
4-10 million	15.9	28.5	413	23	530	22	117	19
1-4 million	16.5	6.7	233	13	289	12	56	9
0.25-1.0 million	8.3	8.1	143	8	217	9	74	12
0.08-0.25 million	3.0	1.9	36	2	72	3	36	6
< 0.08 million	0	0	0	0	0	0	0	0
Rural	3.4	2.7	18	1	24	1	6	1
Total	100.0	100.0	1795	100	2408	100	613	100

[a]Percentages of the population in each income group was assumed to be constant over time.

happens. In the example of Tables 62 and 63, no groups are worse off when either of the new modes is added, so the relation among total benefit numbers is unchanged. Had this not been true, alternative weights could have reversed the results.

Another way of treating the inter-group situation is not to combine the worth from the different groups at all. In this approach each group is considered to be a lobby for its own interests, and will push for the alternative that gives its members the highest return. Thus the decisionmakers can balance the groups that favor a given alternative against the groups that oppose it.*

There are several other ways in which it is possible to portray the benefits, each of which should provide insight into various aspects of the situation. The user benefits may be divided by link and by trip purpose. Also we may wish to subdivide major attributes, e.g., comfort so that worth scores on lower-level attributes may provide feedback to the system design process. The societal benefits may be divided by city ring as well as by income group to distinguish impacts on inner city residents from those on suburbanites. In addition, calculation of the distribution of effects by intensity level, has already been suggested in Table 59.

The sensitivity of the information presented in these benefit exhibits to uncertainty also is a very important consideration. These uncertainties are of many types. It is obvious that the regional environments which have been projected are uncertain, and testing alternative mixes of modes--whose performance levels and societal impacts are also uncertain--against differing environments should provide insights into the probable ranges of effect and hence the relative desirability of each over the lengthy span of its operational life. Other especially important uncertainties include the user demand estimates and the weights which should be assigned to the various user and societal attributes. Efficient computer programs should be able to produce exhibits showing several different values for these variables.

*Any reader who may be bothered at this late point by the question of interpersonal comparisons are referred to the discussion of this issue in Sec. VIII of Ref. 5.

COMBINING BENEFIT, COST AND POLICY INFORMATION

Since our study was undertaken primarily to improve methods of assessing *benefit*, we have deferred until now the consideration of the costs of the alternatives. Let us suppose that, for this example, the two mix of modes improvements have equal costs of $5 billion over the time horizon. This cost is in addition to continuation of current federal, state and local expenditures for evolutionally development, maintenance and operation of the base mix of modes.*

At this point we should more explicitly recognize that we need not be restricted to our two fixed alternatives. There are many ways of varying the design of each alternative. While varying these designs, there are at least three ways in which cost allocations may also change. One way is a reprogramming of the current investment level per year. A second way is a reprogramming of the $5 billion increment that will be made available, both in its timing and in its allocation. A third way is by changing the amount of the increment, that is, spending more or less than the $5 billion. In this case the alternatives and their design variations are no longer equal cost, and a choice among them becomes more complicated.

Variations in the design of the alternatives can be guided by a list of policy options, that is, a set of desired goals as suggested in the hierarchy shown in Fig. 13. Suppose, for example, that we are particularly interested in relocating population out of congested major cities (item 7 in Fig. 13), and in doing this through subsidizing service to low income persons. Suppose in Mix 2, Regional Environment A, we cut the TACV fare to members of the poverty group drastically from 9¢ per mile to 1¢ per mile, and assume that the government supplies the difference by subsidy. Let us also assume a resulting pattern of demand as in Table 64, which includes a large induced demand, since we expect more low income people to travel with a subsidy. We can then calculate that the incremental line-haul user benefit from 1980-2000 to this group will be 225 units and will require an incremental expenditure of $1 billion.

*As mentioned earlier in the volume, we assume constant value dollars throughout the analysis to avoid uncertainties of inflationary effects over time.

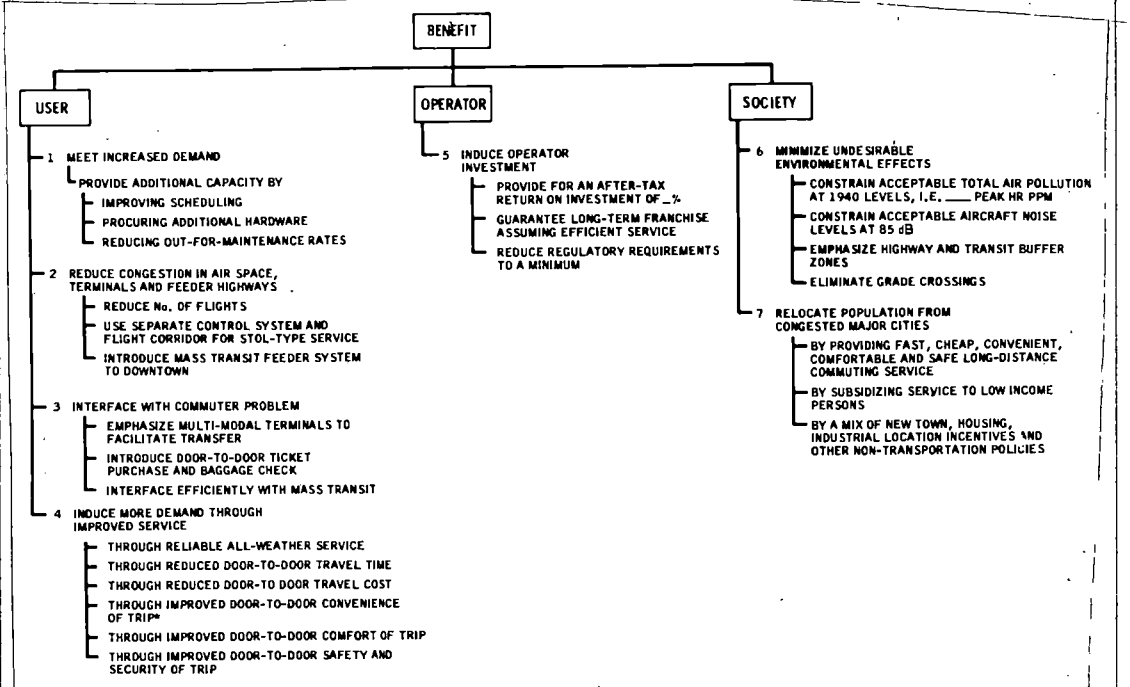


Fig. 13--A mix of policy options

Table 64

DEMAND CHANGES RESULTING FROM SUBSIDY OF TACV TO THE POVERTY GROUP

(In millions of passenger miles)

5-Year Poverty Group Demand

	1980-1990		*1990-2000*	
Mode	*Old Demand*[a]	*New Demand*	*Old Demand*[a]	*New Demand*
TACV	100	2600	190	4240
Auto	700	200	800	200
Bus	700	200	800	200

[a]From Table 14 (Environment A, Mix 2).

Since the 225 replaces the 0 value shown for the poverty group in Table 62 we see that a significant incremental benefit results.

A useful notion, when comparing alternatives and options having differing costs and benefits, is that of *efficiency frontiers*. This concept is illustrated by the example in Fig. 14. In this figure, the incremental benefit from any alternative is plotted against its incremental cost. Mix 3 and Mix 2 are both shown at an incremental cost of $5 billion, in their original designs. The other points show other alternatives and design variations.

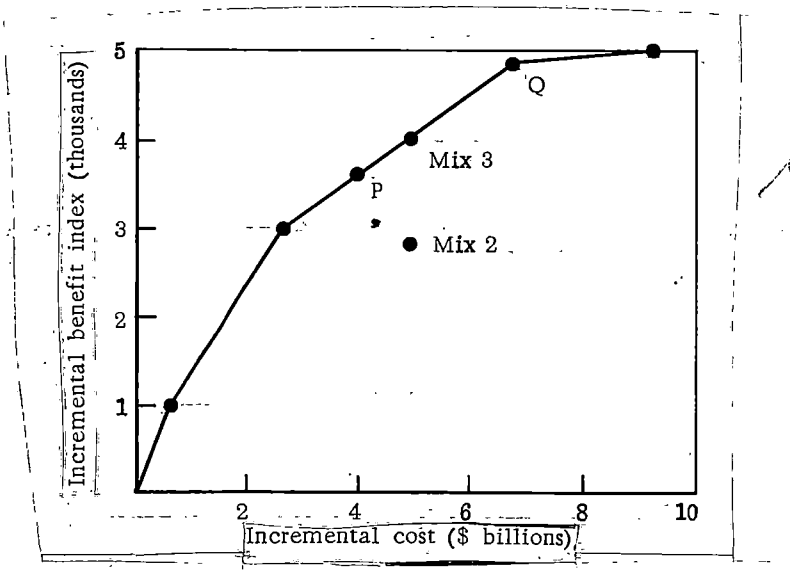


Fig. 14--Illustrating efficient projects

Assuming there is no budget constraint, the set of points connected by the solid line are efficient alternatives, since each additional dollar spent in going from one point on the solid line to the next higher cost one gains the greatest possible extra benefit per dollar. The alternative chosen would be the efficient alternative for which additional expenditures would not give enough additional benefit per dollar to satisfy the decisionmaker, for example, point *Q*. Under a budget constraint, the same criteria would apply to all points at the left of the budget line. For example, under a $5 billion budget constraint, the Mix 3 point would be the efficient point selected. Under a $4 billion budget constraint, point *P* would be the efficient point.

A good way of treating cost considerations is to postulate several different budget constraints and evaluate which alternative is best under each constraint. Of course, we have shown a single valued representation of benefit in this display. We also could construct a three or more dimensional display with user and societal benefits on separate dimensions, and apply the same concept. Such graphical approaches are not to be viewed as mechanical ways of deciding among alternatives, but rather as supplemental methods of displaying the analytical results and aiding decisionmakers in their deliberations.

SUMMARY

We have illustrated several ways of presenting the information generated by our methodology to assist in making a decision. These include summaries of incremental benefits of the alternatives, comparisons of alternatives on the basis of benefit information, and various ways of examining the results for sensitivity. Also suggested are the possibility of improved designs for the alternatives based on various policy options, and cost-benefit tradeoffs for projects of differing cost. Probably no one of these techniques is sufficient. Instead various mixes of them should be useful in deciding among alternative transportation investments.

A P P E N D I X

Table 65

ATTRIBUTE PERFORMANCE VALUES

Mode: TACV; Trip: New York-Washington, D.C.; Line-haul

Attribute	Performance Value
Travel time, avg speed, mph	250
Travel cost, $/mi	.09
Safety and security	
Death, prob/mi	3×10^{-9}
Injury, prob/mi	6×10^{-8}
Intermittent optical stimulation, prob/mi	(b)
Optokinetic nystagmus, prob/mi	(b)
Sickness, prob/hr	$.1 \times 10^{-4}$
Rape, prob/transfer	(b)
Assault, prob/transfer	(b)
Insult, prob/transfer	(b)
Anxiety over transfers, no. line-haul transfers	(c)
Auto	
Stolen, prob/hr	(c)
Damage[d]	
Minor, prob/mi	(c)
Moderate, prob/mi	(c)
Major, prob/mi	(c)
Luggage	
Lost, prob/transfer	1×10^{-3}
Stolen, prob/transfer	$.5 \times 10^{-3}$
Damage[d]	
Minor, prob/transfer	1×10^{-3}
Moderate, prob/transfer	$.2 \times 10^{-3}$
Major, prob/transfer	$.05 \times 10^{-3}$
Clothing damaged, prob/hr	1×10^{-4}
Valuables	
Lost, prob/hr	2×10^{-4}
Stolen, prob/hr	1×10^{-4}
Damaged, prob/hr	$.5 \times 10^{-4}$
Convenience	
Waiting for vehicle	
Standing, time	(c)
Sitting, time > .25 hr	(c)
Overrun, > .1 hr as fraction of sched. time	0
Vehicle maintenance responsibility, direct worth estimate	0
Auto handling, time in parking, returning, searching	(c)
Auto loading, or unloading, time	(c)
Driving responsibility[d]	
Light traffic	
Good weather, day	(c)
Good weather, night	(c)
Rain, day	(c)
Rain, night	(c)
Snow, day	(c)
Snow, night	(c)
Convenience--continued	
Driving responsibility--continued	
Moderate, high speed traffic	
Good weather, day	(c)
Good weather, night	(c)
Rain, day	(c)
Rain, night	(c)
Moderate, downtown traffic	
Good weather, day	(c)
Good weather, night	(c)
Rain, day	(c)
Rain, night	(c)
Snow, day	(c)
Snow, night	(c)
Heavy, downtown traffic	
Good weather, day	(c)
Good weather, night	(c)
Rain, day	(c)
Rain, night	(c)
Snow, day	(c)
Snow, night	(c)
Luggage claim, time/mode	0
Queue time, time/mode	.1
Orientation, time/mode	.02
Boarding, time/mode	.03
Baggage checking, time/mode	.01
Walking, mi/transfer	.1
Luggage capacity, need for excess, -1.0 if needed	0
Group size capacity, need for excess, -1.0 if needed	0
Comfort	
Acceleration[d]	
Time subjected to .25 g's	(b)
Time subjected to .50 g's	(b)
Time subjected to 1.0 g	(b)
Jerk, maximum, g/sec	(b)
Vibration, direct worth estimate/hr	(b)
Pressure change[d]	
Time subjected to 7 psf/min	(b)
Time subjected to 15 psf/min	(b)
Crowdedness[d]	
Seated	
Time in 8 sq ft/person	(b)
Time in 6 sq ft/person	(b)
Standing	
Time in 10 sq ft/person	(b)
Comfort--continued	
Crowdedness--continued	
Standing--continued	
Time in 4 sq/ft person	(b)
Crampedness, subj. est./hr	-.01
Privacy, direct worth est./mode	-.05
Temperature, humidity, direct worth estimate	(b)
Ventilation, time to change air	(b)
Spectral const.[d]	
Time in mercury vapor light	(b)
Time in sodium lamp light	(b)
Color surroundings, direct worth estimate	(b)
Glare[d]	
Time in max/avg intensity ratio of 10	.1
Time in max/avg intensity ratio of 100	(b)
Display, direct worth estimate	(b)
Noise, direct worth/hr[d]	
50-70 dB	-.02
70-90 dB	(b)
90-110 dB	(b)
110-145 dB	(b)
Visual entertainment, 0 if no vis. ent., +1 if yes	0
Stereo, 0 if no stereo, +1 if yes	1
Meals	
0 if no snack, +1 if yes	1
0 if no economy meal, +1 if yes	0
0 if no full meal, +1 if yes	0
Hostess, 0 if no hostess, +1 if yes	1
Aesthetics, direct worth estimate	
Of vehicle	.2
From window	-.2
Of terminal	.2
Ownership, +1 if vehicle owned by traveler	0
Prestige	
+1 if first class	0
+1 if prestige mode	1
Experience, +1 if choice of experience available	0

[a] Careful reading will reveal that a few attributes have been modified or consolidated for the hierarchy of user attributes appearing in Vol. II.

[b] Negligible; zero as far as the computer is concerned.

[c] Not applicable to line-haul portion of trip. Associated with access and egress links for computational purposes.

[d] Shown as multiple attributes for ease of handling various levels of effect.

Table 66

WORTH CURVE INFORMATION

Attribute	Physical Measure	Value of Physical Measure at -1.0 Worth Score
Time	Time made useless in one day, hr	6.67
Cost	Trip cost, $	50.0
Safety & Security (anxiety associated)	Probability of occurrence in foreseeable trips	
Personal safety		
Death	Same	.0001
Injury	Same	.0014
Intermittent optical stimulation	Same	.0043
Optokinetic nystagmus	Same	.043
Sickness	Same	.044
Security of person		
Rape	Same	.0027
Assault	Same	.044
Insult	Same	.52
Anxiety over transfers	Number of foreseen line-haul transfers	5.0
Security of property	Foreseen probability of occurrences	
Auto		
Stolen	Same	.01
Damaged		
Minor	Same	.10
Moderate	Same	.01
Major	Same	.005
Luggage		
Lost	Same	.05
Stolen	Same	.05
Damaged	Same	.1
Clothing		
Damaged	Same	.1
Valuables	Same	.01
Lost	Same	.01
Stolen	Same	.01
Damaged	Same	.02
Convenience (responsibility-associated)		
Of schedule (timing, frequency, and reliability)		
Access reliability (pad time in gate area)	Time spent seated after 15 min, gate area, hr	1.5
Line-haul reliability (schedule overrun time)	Overrun time after 10% of scheduled time, as a fraction of the scheduled time	1.0
Waiting for access/egress mode	Time spent waiting, standing, hr	.75
Personal vehicle responsibilities		
Searching for parked vehicle or renting vehicle	Time spent searching, hr	1.0
Loading personal vehicle	Time spent loading, hr	2.0
Responsibility for driving	Time spent driving, hr	
Light traffic		
Good weather, day	Same	48.0
Good weather, night	Same	28.0
Rain, day	Same	28.0
Rain, night	Same	16.0
Snow, day	Same	8.0
Snow, night	Same	4.0
Moderate, high-speed traffic		
Good weather, day	Same	40.0
Good weather, night	Same	20.0
Rain, day	Same	20.0
Rain, night	Same	12.0
Moderate, downtown traffic		
Good weather, day	Same	12.0
Good weather, night	Same	8.0
Rain, day	Same	8.0
Rain, night	Same	4.0
Snow, day	Same	4.0
Snow, night	Same	2.0
Heavy, downtown traffic		
Good weather, day	Same	6.0
Good weather, night	Same	4.0
Rain, day	Same	4.0
Rain, night	Same	2.0
Snow, day	Same	2.0
Snow, night	Same	1.2
Parking vehicle or returning rented vehicle	Time spent parking or returning, hr	1.0
Unloading personal vehicle	Time spent unloading, hr	2.0
Responsibility for maintenance of vehicle	Direct worth estimate for mode involving responsibility	(-.05, 0)[a]
Convenience--continued		
Terminal responsibilities		
Orientation (attitude of carrier/availability of information)	Time spent in orientation, hr	.4
Wait in queue	Time spent in queue, hr	1.0
Checking baggage	Time spent in checking, hr	.33
Boarding	Time spent in boarding, hr	.4
Claiming baggage	Time spent in claiming, hr	1.5
Access/Egress		
Walk to pick-up point	Distance walked, mi	2.0
Physical constraints		
Constraint on luggage	Is traveler constrained or not?	(0 or -1.0)[b]
Constraint on group size	Same	(0 or -1.0)[b]
Comfort		
Proprioception		
Acceleration	Time subjected to g level, hr	
.25 g	Same	.17
.50 g	Same	.033
1.0 g	Same	.008
Jerk	Maximum jerk experienced (g/sec)	2.0
Vibration	Direct worth estimate per hour	(-1.0, 0)[a]
Pressure changes		
± 7 lb/sq ft/min	Time subjected to change, hr	1.0
± 15 lb/sq ft/min	Same	.02
Crowdedness	Time subjected to crowded conditions, hr	
8 sq ft/person, seated	Same	24.0
6 sq ft/person, seated	Same	13.0
10 sq ft/person, standing	Same	2.0
4 sq ft/person, standing	Same	.5
Crampedness	Direct worth estimate per hour	(-1.0, 0)[a]
Lack of privacy	Direct worth estimate	(-.05, 0)[a]
Environmental		
Temperature, humidity	Direct worth estimate	(-.05, 0)[a]
Ventilation	Average time for air change, hr	1.0
Vision and displays		
Spectral constitution	Time subjected to spectrum, hr	
Mercury vapor		3.0
Sodium		1.5
Color of surroundings	Direct worth estimate of color scheme	(-.03, +.03)[a]
Glare/shadow	Time subjected to glare, hr	
Ratio max/average intensity		
10		5.0
100		.17
Displays	Direct worth estimate of location, size, and shape and lighting of displays	(-.05, 0)[a]
Audition		
Noise level		
50-70 decibels	Direct worth estimate per hour	(-.02, 0)[a]
70-90 decibels	Time of exposure to noise, hr	5.0
90-110 decibels	Same	.17
110-145 decibels	Same	0.0
Entertainment		
Visual (movies, TV displays, etc.)	Presence or absence of attribute	(0 or +.1)[b]
Stereo	Same	(0 or +.02)[b]
Meals	Same	
Snack	Same	(0 or +.04)[b]
Economy	Same	(0 or +.10)[b]
Full meal	Same	(0 or +.04)[b]
Hostess/attendants		
Aesthetics	Direct worth estimate	
Vehicle	Same	(-.01, +.01)[a]
View from window	Same	(-.03, +.03)[a]
In terminal	Same	(-.03, +.03)[a]
Psychological	Presence or absence of attribute	
Satisfaction of ownership	Same	(0 or +.06)[b]
Prestige	Same	
First class vs economy	Same	(0 or +.04)[b]
Mode associated	Same	(0 or +.04)[b]
Choice of experience	Same	(0 or +.1)[b]

NOTE: Assuming (1) 0 to -1.0 scales, (2) all curves are linear, and (3) weights assigned to the attributes are included in the curves and sum to 1. Weights used are for middle income travelers on business.

[a] Permissible range for a direct worth estimate.

[b] Binary choice for a worth score.

Table 67

SAMPLE OUTPUT: ANALYSIS OF LINE-HAUL USER BENEFITS

LINE-HAUL WORTH (IN MILLIONS OF WORTH POINTS)

REGIONAL ENVIRONMENT A, MIX 1

	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
AUTO						
Poverty ($ 0 - 4K)						
Safety/Secur	1.8	1.8	1.8	2.5	2.9	2.9
Convenience	.5	.5	.5	.8	.9	.9
Comfort	1.4	1.4	1.4	2.0	2.3	2.3
Subtotal	3.7	3.7	3.7	5.2	6.0	6.0
Time	.2	.2	.2	.3	.3	.3
Cost	6.6	6.6	6.6	9.2	10.6	10.6
Subtotal	6.8	6.8	6.8	9.5	10.9	10.9
Total	10.5	10.5	10.5	14.7	16.8	16.8
Lower ($ 4K - 10K)						
Safety/Secur	26.1	28.2	30.7	33.2	35.7	38.6
Convenience	15.8	17.1	18.6	20.1	21.6	23.3
Comfort	20.7	22.4	24.3	26.3	28.3	30.6
Subtotal	62.5	67.6	73.6	79.6	85.6	92.4
Time	6.9	7.5	8.2	8.8	9.5	10.3
Cost	62.0	67.1	73.0	79.0	84.9	91.7
Subtotal	68.9	74.6	81.2	87.8	94.4	102.0
Total	131.4	142.2	154.8	167.4	180.0	194.4
Middle ($ 10K - 20K)						
Safety/Secur	16.8	17.9	19.6	21.1	22.8	24.6
Convenience	12.7	13.5	14.9	15.9	17.3	18.6
Comfort	19.9	21.2	23.3	25.0	27.1	29.3
Subtotal	49.4	52.6	57.8	62.0	67.3	72.5
Time	5.4	5.7	6.3	6.7	7.3	7.9
Cost	26.6	28.3	31.1	33.4	36.2	39.1
Subtotal	32.0	34.0	37.4	40.1	43.5	46.9
Total	81.4	86.6	95.2	102.1	110.8	119.4
Upper (>$20K)						
Safety/Secur	1.4	1.8	1.8	2.1	2.5	2.5
Convenience	1.2	1.5	1.5	1.8	2.1	2.1
Comfort	1.7	2.1	2.1	2.5	3.0	3.0
Subtotal	4.3	5.4	5.4	6.5	7.5	7.5
Time	.6	.7	.7	.9	1.0	1.0
Cost	1.5	1.9	1.9	2.3	2.6	2.6
Subtotal	2.1	2.6	2.6	3.1	3.6	3.6
Total	6.4	8.0	8.0	9.6	11.2	11.2
TOTAL	229.7	247.3	268.5	293.9	318.8	341.9

LINE-HAUL WORTH (IN MILLIONS OF WORTH POINTS)

REGIONAL ENVIRONMENT A, MIX 1

	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
BUS						
Poverty ($ 0 - 4K)						
Safety/Secur	1.7	2.0	2.0	2.4	2.7	2.7
Convenience	.7	.8	.8	1.0	1.1	1.1
Comfort	.8	1.0	1.0	1.1	1.3	1.3
Subtotal	3.2	3.8	3.8	4.4	5.1	5.1
Time	.2	.3	.3	.3	.3	.3
Cost	6.6	8.0	8.0	9.3	10.6	10.6
Subtotal	6.9	8.2	8.2	9.6	11.0	11.0
Total	10.0	12.0	12.0	14.0	16.0	16.0
Lower ($ 4K - 10K)						
Safety/Secur	6.0	6.7	7.4	7.7	8.4	9.1
Convenience	4.9	5.5	6.0	6.3	6.9	7.4
Comfort	2.9	3.2	3.6	3.7	4.1	4.4
Subtotal	13.9	15.4	17.0	17.8	19.3	20.8
Time	1.9	2.1	2.3	2.4	2.6	2.8
Cost	15.4	17.1	18.8	19.6	21.4	23.1
Subtotal	17.3	19.2	21.1	22.1	24.0	25.9
Total	31.2	34.6	38.1	39.8	43.3	46.7
Middle ($ 10K - 20K)						
Safety/Secur	3.0	3.0	3.4	3.7	4.0	4.4
Convenience	3.1	3.1	3.4	3.8	4.1	4.4
Comfort	2.2	2.2	2.4	2.7	2.9	3.2
Subtotal	8.3	8.3	9.2	10.1	11.1	12.0
Time	1.1	1.1	1.3	1.4	1.5	1.6
Cost	5.1	5.1	5.7	6.3	6.8	7.4
Subtotal	6.3	6.3	7.0	7.7	8.4	9.0
Total	14.6	14.6	16.2	17.8	19.4	21.0
Upper (>$20K)						
Safety/Secur	.0	.0	.0	.0	.0	.0
Convenience	.0	.0	.0	.0	.0	.0
Comfort	.0	.0	.0	.0	.0	.0
Subtotal	.0	.0	.0	.0	.0	.0
Time	.0	.0	.0	.0	.0	.0
Cost	.0	.0	.0	.0	.0	.0
Subtotal	.0	.0	.0	.0	.0	.0
Total	.0	.0	.0	.0	.0	.0
TOTAL	55.8	61.2	66.3	71.7	78.7	83.8

LINE-HAUL WORTH (IN MILLIONS OF WORTH POINTS)

REGIONAL ENVIRONMENT A, MIX 1

	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
RAIL						
Poverty ($ 0 - 4K)						
Safety/Secur	.7	.7	.7	.7	.7	1.1
Convenience	.2	.2	.2	.2	.2	.4
Comfort	.5	.5	.5	.5	.5	.8
Subtotal	1.5	1.5	1.5	1.5	1.5	2.2
Time	.1	.1	.1	.1	.1	.2
Cost	2.4	2.4	2.4	2.4	2.4	3.6
Subtotal	2.5	2.5	2.5	2.5	2.5	3.8
Total	4.0	4.0	4.0	4.0	4.0	6.0
Lower ($ 4K - 10K)						
Safety/Secur	4.4	4.7	5.1	5.8	6.2	6.5
Convenience	2.8	3.1	3.3	3.8	4.0	4.2
Comfort	3.1	3.4	3.6	4.1	4.4	4.7
Subtotal	10.3	11.1	12.0	13.7	14.6	15.4
Time	2.0	2.2	2.4	2.7	2.9	3.1
Cost	9.1	9.9	10.7	12.2	13.0	13.7
Subtotal	11.2	12.1	13.0	14.9	15.8	16.8
Total	21.5	23.3	25.0	28.6	30.4	32.2
Middle ($ 10K - 20K)						
Safety/Secur	5.8	6.2	6.5	7.3	8.0	8.3
Convenience	4.7	5.0	5.3	5.9	6.4	6.7
Comfort	6.2	6.6	7.0	7.8	8.5	8.9
Subtotal	16.7	17.7	18.8	20.9	23.0	24.0
Time	3.3	3.5	3.7	4.1	4.5	4.7
Cost	8.1	8.6	9.1	10.2	11.2	11.7
Subtotal	11.4	12.1	12.8	14.2	15.7	16.4
Total	28.1	29.9	31.6	35.1	38.6	40.4
Upper (>$20K)						
Safety/Secur	1.5	1.5	1.8	2.2	2.2	2.5
Convenience	1.3	1.3	1.6	1.9	1.9	2.3
Comfort	1.6	1.6	1.9	2.3	2.3	2.7
Subtotal	4.3	4.3	5.4	6.4	6.4	7.5
Time	1.0	1.0	1.3	1.5	1.5	1.8
Cost	1.4	1.4	1.7	2.0	2.0	2.4
Subtotal	2.4	2.4	3.0	3.6	3.6	4.2
Total	6.7	6.7	8.3	10.0	10.0	11.7
TOTAL	60.2	63.8	69.0	77.7	83.0	90.9

LINE-HAUL WORTH (IN MILLIONS OF WORTH POINTS)

REGIONAL ENVIRONMENT A, MIX 1

	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
AIR						
Poverty ($ 0 - 4K)						
Safety/Secur	.0	.0	.0	.0	.0	.0
Convenience	.0	.0	.0	.0	.0	.0
Comfort	.0	.0	.0	.0	.0	.0
Subtotal	.0	.0	.0	.0	.0	.0
Time	.0	.0	.0	.0	.0	.0
Cost	.0	.0	.0	.0	.0	.0
Subtotal	.0	.0	.0	.0	.0	.0
Total	.0	.0	.0	.0	.0	.0
Lower ($ 4K - 10K)						
Safety/Secur	1.6	1.6	1.6	2.0	2.0	2.0
Convenience	.8	.8	.8	1.1	1.1	1.1
Comfort	1.0	1.0	1.0	1.2	1.2	1.2
Subtotal	3.4	3.4	3.4	4.2	4.2	4.2
Time	.9	.9	.9	1.2	1.2	1.2
Cost	2.6	2.6	2.6	3.3	3.3	3.3
Subtotal	3.6	3.6	3.6	4.5	4.5	4.5
Total	7.0	7.0	7.0	8.7	8.7	8.7
Middle ($ 10K - 20K)						
Safety/Secur	8.6	9.4	10.1	10.9	14.0	12.5
Convenience	5.8	6.3	6.8	7.4	9.5	8.4
Comfort	8.2	8.9	9.6	10.4	13.4	11.9
Subtotal	22.5	24.6	26.6	28.7	36.9	32.8
Time	6.2	6.7	7.3	7.9	10.1	9.0
Cost	9.6	10.5	11.3	12.2	15.7	14.0
Subtotal	15.8	17.2	18.6	20.1	25.8	22.9
Total	38.3	41.8	45.3	48.7	62.7	55.7
Upper (>$20K)						
Safety/Secur	3.9	3.9	4.3	4.7	5.1	5.5
Convenience	2.9	2.9	3.2	3.5	3.8	4.1
Comfort	3.7	3.7	4.1	4.5	4.8	5.2
Subtotal	10.5	10.5	11.6	12.6	13.7	14.7
Time	3.5	3.5	3.9	4.2	4.6	4.9
Cost	2.9	2.9	3.2	3.5	3.8	4.1
Subtotal	6.4	6.4	7.1	7.7	8.3	9.0
Total	16.9	16.9	18.6	20.3	22.0	23.7
TOTAL	62.2	65.7	70.8	77.8	93.4	88.1

GRAND TOTALS

	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
Poverty	24.5	26.6	26.6	32.8	36.9	38.9
Lower	191.0	207.0	224.8	244.5	262.4	282.0
Middle	162.3	172.7	188.3	203.8	231.5	236.6
Upper	30.0	31.6	34.9	39.9	43.2	46.5
GRAND TOTAL	407.8	437.9	474.6	521.0	574.0	604.0

Table 67--continued

LINE-HAUL WORTH (IN MILLIONS OF WORTH POINTS)

REGIONAL ENVIRONMENT A, MIX 2

	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
AUTO						
Poverty ($ 0 - 4K)						
Safety/Secur	1.8	1.8	2.5	2.5	2.9	2.9
Convenience	.5	.5	.8	.8	.9	.9
Comfort	1.4	1.4	2.0	2.0	2.3	2.3
Subtotal	3.7	3.7	5.2	5.2	6.0	6.0
Time	.2	.2	.3	.3	.3	.3
Cost	6.6	6.6	9.2	9.2	10.6	10.6
Subtotal	6.8	6.8	9.5	9.5	10.9	10.9
Total	10.5	10.5	14.7	14.7	16.8	16.8
Lower ($ 4K - 10K)						
Safety/Secur	26.1	28.2	29.6	32.5	35.0	37.5
Convenience	15.8	17.1	17.9	19.7	21.2	22.7
Comfort	20.7	22.4	23.5	25.8	27.7	29.7
Subtotal	62.5	67.6	71.0	77.9	83.9	89.9
Time	6.9	7.5	7.9	8.6	9.3	10.0
Cost	62.0	67.1	70.5	77.3	83.2	89.1
Subtotal	68.9	74.6	78.4	85.9	92.5	99.1
Total	131.4	142.2	149.4	163.8	176.4	189.0
Middle ($ 10K - 20K)						
Safety/Secur	16.8	17.9	14.3	15.7	16.8	17.9
Convenience	12.7	13.5	10.8	11.9	12.7	13.5
Comfort	19.9	21.2	17.0	18.7	19.9	21.2
Subtotal	49.4	52.6	42.0	46.2	49.4	52.6
Time	5.4	5.7	4.6	5.0	5.4	5.7
Cost	26.6	28.3	22.6	24.9	26.6	28.3
Subtotal	32.0	34.0	27.2	29.9	32.0	34.0
Total	81.4	86.6	69.2	76.2	81.4	86.6
Upper (>$20K)						
Safety/Secur	1.4	1.8	1.1	1.4	1.4	1.4
Convenience	1.2	1.5	.9	1.2	1.2	1.2
Comfort	1.7	2.1	1.3	1.7	1.7	1.7
Subtotal	4.3	5.4	3.2	4.3	4.3	4.3
Time	.6	.7	.4	.6	.6	.6
Cost	1.5	1.9	1.1	1.5	1.5	1.5
Subtotal	2.1	2.6	1.6	2.1	2.1	2.1
Total	6.4	8.0	4.8	6.4	6.4	6.4
TOTAL	229.7	247.3	238.2	261.1	281.0	296.8

LINE-HAUL WORTH (IN MILLIONS OF WORTH POINTS)

REGIONAL ENVIRONMENT A, MIX 2

	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
BUS						
Poverty ($ 0 - 4K)						
Safety/Secur	1.7	2.0	2.4	2.4	2.7	2.7
Convenience	.7	.8	1.0	1.0	1.1	1.1
Comfort	.8	1.0	1.1	1.1	1.3	1.3
Subtotal	3.2	3.8	4.4	4.4	5.1	5.1
Time	.2	.3	.3	.3	.3	.3
Cost	6.6	8.0	9.3	9.3	10.6	10.6
Subtotal	6.9	8.2	9.6	9.6	11.0	11.0
Total	10.0	12.0	14.0	14.0	16.0	16.0
Lower ($ 4K - 10K)						
Safety/Secur	6.0	6.7	7.1	7.7	8.4	8.7
Convenience	4.9	5.5	5.8	6.3	6.9	7.1
Comfort	2.9	3.2	3.4	3.7	4.1	4.2
Subtotal	13.9	15.4	16.2	17.8	19.3	20.1
Time	1.9	2.1	2.2	2.4	2.6	2.7
Cost	15.4	17.1	17.9	19.6	21.4	22.2
Subtotal	17.3	19.2	20.1	22.1	24.0	24.9
Total	31.2	34.6	36.4	39.8	43.3	45.0
Middle ($ 10K - 20K)						
Safety/Secur	3.0	3.0	3.0	3.4	3.4	3.7
Convenience	3.1	3.1	3.1	3.4	3.4	3.8
Comfort	2.2	2.2	2.2	2.4	2.4	2.7
Subtotal	8.3	8.3	8.3	9.2	9.2	10.1
Time	1.1	1.1	1.1	1.3	1.3	1.4
Cost	5.1	5.1	5.1	5.7	5.7	6.3
Subtotal	6.3	6.3	6.3	7.0	7.0	7.7
Total	14.6	14.6	14.6	16.2	16.2	17.8
Upper (>$20K)						
Safety/Secur	.0	.0	.0	.0	.0	.0
Convenience	.0	.0	.0	.0	.0	.0
Comfort	.0	.0	.0	.0	.0	.0
Subtotal	.0	.0	.0	.0	.0	.0
Time	.0	.0	.0	.0	.0	.0
Cost	.0	.0	.0	.0	.0	.0
Subtotal	.0	.0	.0	.0	.0	.0
Total	.0	.0	.0	.0	.0	.0
TOTAL	55.8	61.2	65.0	70.0	75.5	78.9

LINE-HAUL WORTH (IN MILLIONS OF WORTH POINTS)

REGIONAL ENVIRONMENT A, MIX 2

	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
RAIL						
Poverty ($ 0 - 4K)						
Safety/Secur	.7	.7	.0	.0	.0	.0
Convenience	.2	.2	.0	.0	.0	.0
Comfort	.5	.5	.0	.0	.0	.0
Subtotal	1.5	1.5	.0	.0	.0	.0
Time	.1	.1	.0	.0	.0	.0
Cost	2.4	2.4	.0	.0	.0	.0
Subtotal	2.5	2.5	.0	.0	.0	.0
Total	4.0	4.0	.0	.0	.0	.0
Lower ($ 4K - 10K)						
Safety/Secur	4.4	4.7	.0	.0	.0	.0
Convenience	2.8	3.1	.0	.0	.0	.0
Comfort	3.1	3.4	.0	.0	.0	.0
Subtotal	10.3	11.1	.0	.0	.0	.0
Time	2.0	2.2	.0	.0	.0	.0
Cost	9.1	9.9	.0	.0	.0	.0
Subtotal	11.2	12.1	.0	.0	.0	.0
Total	21.5	23.3	.0	.0	.0	.0
Middle ($ 10K - 20K)						
Safety/Secur	5.8	5.8	.0	.0	.0	.0
Convenience	4.7	4.7	.0	.0	.0	.0
Comfort	6.2	6.2	.0	.0	.0	.0
Subtotal	16.7	16.7	.0	.0	.0	.0
Time	3.3	3.3	.0	.0	.0	.0
Cost	8.1	8.1	.0	.0	.0	.0
Subtotal	11.4	11.4	.0	.0	.0	.0
Total	28.1	28.1	.0	.0	.0	.0
Upper (>$20K)						
Safety/Secur	1.5	1.5	.0	.0	.0	.0
Convenience	1.3	1.3	.0	.0	.0	.0
Comfort	1.6	1.6	.0	.0	.0	.0
Subtotal	4.3	4.3	.0	.0	.0	.0
Time	1.0	1.0	.0	.0	.0	.0
Cost	1.4	1.4	.0	.0	.0	.0
Subtotal	2.4	2.4	.0	.0	.0	.0
Total	6.7	6.7	.0	.0	.0	.0
TOTAL	60.2	62.0	.0	.0	.0	.0

LINE-HAUL WORTH (IN MILLIONS OF WORTH POINTS)

REGIONAL ENVIRONMENT A, MIX 2

	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
AIR						
Poverty ($ 0 - 4K)						
Safety/Secur	.0	.0	.0	.0	.0	.0
Convenience	.0	.0	.0	.0	.0	.0
Comfort	.0	.0	.0	.0	.0	.0
Subtotal	.0	.0	.0	.0	.0	.0
Time	.0	.0	.0	.0	.0	.0
Cost	.0	.0	.0	.0	.0	.0
Subtotal	.0	.0	.0	.0	.0	.0
Total	.0	.0	.0	.0	.0	.0
Lower ($ 4K - 10K)						
Safety/Secur	1.6	1.6	.4	.8	.8	.8
Convenience	.8	.8	.2	.4	.4	.4
Comfort	1.0	1.0	.2	.5	.5	.5
Subtotal	3.4	3.4	.8	1.7	1.7	1.7
Time	.9	.9	.2	.5	.5	.5
Cost	2.6	2.6	.7	1.3	1.3	1.3
Subtotal	3.6	3.6	.9	1.8	1.8	1.8
Total	7.0	7.0	1.7	3.5	3.5	3.5
Middle ($ 10K - 20K)						
Safety/Secur	8.6	9.4	3.5	3.9	4.3	4.7
Convenience	5.8	6.3	2.4	2.6	2.9	3.2
Comfort	8.2	8.9	3.3	3.7	4.1	4.5
Subtotal	22.5	24.6	9.2	10.2	11.3	12.3
Time	6.2	6.7	2.5	2.8	3.1	3.4
Cost	9.6	10.5	3.9	4.4	4.8	5.2
Subtotal	15.8	17.2	6.5	7.2	7.9	8.6
Total	38.3	41.8	15.7	17.4	19.2	20.9
Upper (>$20K)						
Safety/Secur	3.9	3.9	2.3	2.7	3.1	3.1
Convenience	2.9	2.9	1.7	2.0	2.3	2.3
Comfort	3.7	3.7	2.2	2.6	3.0	3.0
Subtotal	10.5	10.5	6.3	7.4	8.4	8.4
Time	3.5	3.5	2.1	2.5	2.8	2.8
Cost	2.9	2.9	1.7	2.0	2.3	2.3
Subtotal	6.4	6.4	3.9	4.5	5.1	5.1
Total	16.9	16.9	10.2	11.9	13.5	13.5
TOTAL	62.2	65.7	27.6	32.7	36.2	37.9

Table 67--continued

LINE-HAUL WORTH (IN MILLIONS OF WORTH POINTS)

REGIONAL ENVIRONMENT A, MIX 2

	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
TACV						
Poverty ($ 0 - 4K)						
Safety/Secur	.0	.0	.4	.4	.7	.7
Convenience	.0	.0	.1	.1	.2	.2
Comfort	.0	.0	.3	.3	.6	.6
Subtotal	.0	.0	.8	.8	1.6	1.6
Time	.0	.0	.0	.0	.0	.0
Cost	.0	.0	1.0	1.0	1.9	1.9
Subtotal	.0	.0	1.0	1.0	2.0	2.0
Total	.0	.0	1.9	1.9	3.6	3.6
Lower ($ 4K - 10K)						
Safety/Secur	.0	.0	9.8	10.8	12.0	12.7
Convenience	.0	.0	5.9	6.4	7.2	7.6
Comfort	.0	.0	8.1	8.9	9.9	10.5
Subtotal	.0	.0	23.8	26.1	29.1	30.8
Time	.0	.0	6.1	6.7	7.5	7.9
Cost	.0	.0	16.4	17.9	20.0	21.2
Subtotal	.0	.0	22.5	24.7	27.5	29.2
Total	.0	.0	46.3	50.7	56.6	60.0
Middle ($ 10K - 20K)						
Safety/Secur	.0	.0	31.0	34.6	37.8	40.9
Convenience	.0	.0	23.1	25.8	28.2	30.5
Comfort	.0	.0	38.2	42.6	46.5	50.3
Subtotal	.0	.0	92.4	103.0	112.4	121.7
Time	.0	.0	23.3	26.0	28.3	30.7
Cost	.0	.0	34.4	38.4	41.9	45.3
Subtotal	.0	.0	57.7	64.3	70.2	76.0
Total	.0	.0	150.2	167.3	182.7	197.7
Upper (>$20K)						
Safety/Secur	.0	.0	7.9	8.4	9.5	10.2
Convenience	.0	.0	6.5	6.9	7.8	8.4
Comfort	.0	.0	9.7	10.4	11.7	12.6
Subtotal	.0	.0	24.0	25.8	28.9	31.2
Time	.0	.0	7.4	7.9	8.9	9.6
Cost	.0	.0	5.8	6.3	7.0	7.6
Subtotal	.0	.0	13.2	14.2	15.9	17.2
Total	.0	.0	37.2	40.0	44.8	48.4
TOTAL	.0	.0	235.5	259.9	287.7	309.6

LINE-HAUL WORTH (IN MILLIONS OF WORTH POINTS)

REGIONAL ENVIRONMENT A, MIX 2

	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
STOL						
Poverty ($ 0 - 4K)						
Safety/Secur	.0	.0	.0	.0	.0	.0
Convenience	.0	.0	.0	.0	.0	.0
Comfort	.0	.0	.0	.0	.0	.0
Subtotal	.0	.0	.0	.0	.1	.1
Time	.0	.0	.0	.0	.0	.0
Cost	.0	.0	.0	.0	.1	.1
Subtotal	.0	.0	.0	.0	.1	.1
Total	.0	.0	.0	.0	.2	.2
Lower ($ 4K - 10K)						
Safety/Secur	.0	.0	.0	.2	.9	1.0
Convenience	.0	.0	.0	.1	.5	.5
Comfort	.0	.0	.0	.1	.6	.6
Subtotal	.0	.0	.0	.5	2.0	2.2
Time	.0	.0	.0	.1	.6	.6
Cost	.0	.0	.0	.3	1.3	1.4
Subtotal	.0	.0	.0	.5	1.9	2.0
Total	.0	.0	.0	1.0	3.9	4.2
Middle ($ 10K - 20K)						
Safety/Secur	.0	.0	.0	.7	3.0	3.2
Convenience	.0	.0	.0	.5	2.1	2.2
Comfort	.0	.0	.0	.7	2.9	3.1
Subtotal	.0	.0	.0	1.9	8.1	8.5
Time	.0	.0	.0	.5	2.2	2.3
Cost	.0	.0	.0	.7	2.9	3.0
Subtotal	.0	.0	.0	1.2	5.1	5.3
Total	.0	.0	.0	3.2	13.1	13.8
Upper (>$20K)						
Safety/Secur	.0	.0	.0	.2	.7	.8
Convenience	.0	.0	.0	.1	.6	.6
Comfort	.0	.0	.0	.2	.7	.7
Subtotal	.0	.0	.0	.5	2.0	2.1
Time	.0	.0	.0	.2	.7	.7
Cost	.0	.0	.0	.1	.5	.5
Subtotal	.0	.0	.0	.3	1.1	1.2
Total	.0	.0	.0	.8	3.1	3.3
TOTAL	.0	.0	.0	5.0	20.3	21.5

GRAND TOTALS

	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
Poverty	24.5	26.6	30.7	30.7	36.6	36.6
Lower	191.0	207.0	233.8	258.8	283.7	301.7
Middle	162.3	171.0	249.7	280.2	312.5	336.7
Upper	30.0	31.6	52.2	59.1	67.9	71.6
GRAND TOTAL	407.8	436.2	566.2	628.7	700.7	746.6

Table 67--continued

LINE-HAUL WORTH (IN MILLIONS OF WORTH POINTS)

REGIONAL ENVIRONMENT A, MIX 3

	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
AUTO						
Poverty ($ 0 - 4K)						
Safety/Secur	1.8	1.8	2.1	2.1	2.5	2.5
Convenience	.5	.5	.6	.6	.8	.8
Comfort	1.4	1.4	1.7	1.7	2.0	2.0
Subtotal	3.7	3.7	4.5	4.5	5.2	5.2
Time	.2	.2	.2	.2	.3	.3
Cost	6.6	6.6	7.9	7.9	9.2	9.2
Subtotal	6.8	6.8	8.1	8.1	9.5	9.5
Total	10.5	10.5	12.6	12.6	14.7	14.7
Lower ($ 4K - 10K)						
Safety/Secur	26.1	28.2	20.0	21.4	23.2	25.0
Convenience	15.8	17.1	12.1	13.0	14.0	15.1
Comfort	20.7	22.4	15.8	17.0	18.4	19.8
Subtotal	62.5	67.6	47.9	51.4	55.6	59.9
Time	6.9	7.5	5.3	5.7	6.2	6.7
Cost	62.0	67.1	47.5	50.9	55.2	59.4
Subtotal	68.9	74.6	52.9	56.6	61.4	66.1
Total	131.4	142.2	100.8	108.0	117.0	126.0
Middle ($ 10K - 20K)						
Safety/Secur	16.8	17.9	9.6	10.4	11.1	12.1
Convenience	12.7	13.5	7.3	7.8	8.4	9.2
Comfort	19.9	21.2	11.4	12.3	13.1	14.4
Subtotal	49.4	52.6	28.4	30.5	32.6	35.7
Time	5.4	5.7	3.1	3.3	3.5	3.9
Cost	26.6	28.3	15.3	16.4	17.5	19.2
Subtotal	32.0	34.0	18.4	19.7	21.1	23.1
Total	81.4	86.6	46.7	50.2	53.7	58.9
Upper (>$20K)						
Safety/Secur	1.4	1.8	.7	.7	1.1	1.1
Convenience	1.2	1.5	.6	.6	.9	.9
Comfort	1.7	2.1	.8	.8	1.3	1.3
Subtotal	4.3	5.4	2.2	2.2	3.2	3.2
Time	.6	.7	.3	.3	.4	.4
Cost	1.5	1.9	.8	.8	1.1	1.1
Subtotal	2.1	2.6	1.0	1.0	1.6	1.6
Total	6.4	8.0	3.2	3.2	4.8	4.8
TOTAL	229.7	247.3	163.4	174.0	190.2	204.4

LINE-HAUL WORTH (IN MILLIONS OF WORTH POINTS)

REGIONAL ENVIRONMENT A, MIX 3

	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
BUS						
Poverty ($ 0 - 4K)						
Safety/Secur	1.7	2.0	2.0	2.4	2.7	2.7
Convenience	.7	.8	.8	1.0	1.1	1.1
Comfort	.8	1.0	1.0	1.1	1.3	1.3
Subtotal	3.2	3.8	3.8	4.4	5.1	5.1
Time	.2	.3	.3	.3	.3	.3
Cost	6.6	8.0	8.0	9.3	10.6	10.6
Subtotal	6.9	8.2	8.2	9.6	11.0	11.0
Total	10.0	12.0	12.0	14.0	16.0	16.0
Lower ($ 4K - 10K)						
Safety/Secur	6.0	6.7	7.4	7.7	8.4	9.1
Convenience	4.9	5.5	6.0	6.3	6.9	7.4
Comfort	2.9	3.2	3.6	3.7	4.1	4.4
Subtotal	13.9	15.4	17.0	17.8	19.3	20.8
Time	1.9	2.1	2.3	2.4	2.6	2.8
Cost	15.4	17.1	18.8	19.6	21.4	23.1
Subtotal	17.3	19.2	21.1	22.1	24.0	25.9
Total	31.2	34.6	38.1	39.8	43.3	46.7
Middle ($ 10K - 20K)						
Safety/Secur	3.0	3.0	3.4	3.7	4.0	4.4
Convenience	3.1	3.1	3.4	3.8	4.1	4.4
Comfort	2.2	2.2	2.4	2.7	2.9	3.2
Subtotal	8.3	8.3	9.2	10.1	11.1	12.0
Time	1.1	1.1	1.3	1.4	1.5	1.6
Cost	5.1	5.1	5.7	6.3	6.8	7.4
Subtotal	6.3	6.3	7.0	7.7	8.4	9.0
Total	14.6	14.6	16.2	17.8	19.4	21.0
Upper (>$20K)						
Safety/Secur	.0	.0	.0	.0	.0	.0
Convenience	.0	.0	.0	.0	.0	.0
Comfort	.0	.0	.0	.0	.0	.0
Subtotal	.0	.0	.0	.0	.0	.0
Time	.0	.0	.0	.0	.0	.0
Cost	.0	.0	.0	.0	.0	.0
Subtotal	.0	.0	.0	.0	.0	.0
Total	.0	.0	.0	.0	.0	.0
TOTAL	56.8	61.2	66.3	71.7	78.7	83.8

LINE-HAUL WORTH (IN MILLIONS OF WORTH POINTS)

REGIONAL ENVIRONMENT A, MIX 3

	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
RAIL						
Poverty ($ 0 - 4K)						
Safety/Secur	.7	.7	.4	.4	.4	.7
Convenience	.2	.2	.1	.1	.1	.2
Comfort	.5	.5	.3	.3	.3	.5
Subtotal	1.5	1.5	.7	.7	.7	1.5
Time	.1	.1	.1	.1	.1	.1
Cost	2.4	2.4	1.2	1.2	1.2	2.4
Subtotal	2.5	2.5	1.3	1.3	1.3	2.5
Total	4.0	4.0	2.0	2.0	2.0	4.0
Lower ($ 4K - 10K)						
Safety/Secur	4.4	4.7	4.7	5.1	5.4	5.8
Convenience	2.8	3.1	3.1	3.3	3.5	3.8
Comfort	3.1	3.4	3.4	3.6	3.9	4.1
Subtotal	10.3	11.1	11.1	12.0	12.9	13.7
Time	2.0	2.2	2.2	2.4	2.6	2.7
Cost	9.1	9.9	9.9	10.7	11.4	12.2
Subtotal	11.2	12.1	12.1	13.0	14.0	14.9
Total	21.5	23.3	23.3	25.0	26.8	28.6
Middle ($ 10K - 20K)						
Safety/Secur	5.8	6.2	2.9	3.3	3.3	3.6
Convenience	4.7	5.0	2.3	2.6	2.6	2.9
Comfort	6.2	6.6	3.1	3.5	3.5	3.9
Subtotal	16.7	17.7	8.4	9.4	9.4	10.4
Time	3.3	3.5	1.6	1.8	1.8	2.0
Cost	8.1	8.6	4.1	4.6	4.6	5.1
Subtotal	11.4	12.1	5.7	6.4	6.4	7.1
Total	28.1	29.9	14.0	15.8	15.8	17.6
Upper (>$20K)						
Safety/Secur	1.5	1.5	.7	.7	.7	1.1
Convenience	1.3	1.3	.6	.6	.6	1.0
Comfort	1.6	1.6	.8	.8	.8	1.2
Subtotal	4.3	4.3	2.1	2.1	2.1	3.2
Time	1.0	1.0	.5	.5	.5	.8
Cost	1.4	1.4	.7	.7	.7	1.0
Subtotal	2.4	2.4	1.2	1.2	1.2	1.8
Total	6.7	6.7	3.3	3.3	3.3	5.0
TOTAL	60.2	63.8	42.6	46.2	48.0	55.2

LINE-HAUL WORTH (IN MILLIONS OF WORTH POINTS)

REGIONAL ENVIRONMENT A, MIX 3

	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
AIR						
Poverty ($ 0 - 4K)						
Safety/Secur	.0	.0	.0	.0	.0	.0
Convenience	.0	.0	.0	.0	.0	.0
Comfort	.0	.0	.0	.0	.0	.0
Subtotal	.0	.0	.0	.0	.0	.0
Time	.0	.0	.0	.0	.0	.0
Cost	.0	.0	.0	.0	.0	.0
Subtotal	.0	.0	.0	.0	.0	.0
Total	.0	.0	.0	.0	.0	.0
Lower ($ 4K - 10K)						
Safety/Secur	1.6	1.6	1.2	1.2	1.2	1.6
Convenience	.8	.8	.6	.6	.6	.8
Comfort	1.0	1.0	.7	.7	.7	1.0
Subtotal	3.4	3.4	2.5	2.5	2.5	3.4
Time	.9	.9	.7	.7	.7	.9
Cost	2.6	2.6	2.0	2.0	2.0	2.6
Subtotal	3.6	3.6	2.7	2.7	2.7	3.6
Total	7.0	7.0	5.2	5.2	5.2	7.0
Middle ($ 10K - 20K)						
Safety/Secur	8.6	9.4	5.5	5.9	6.2	7.0
Convenience	5.8	6.3	3.7	3.9	4.2	4.7
Comfort	8.2	8.9	5.2	5.6	5.9	6.7
Subtotal	22.5	24.6	14.3	15.4	16.4	18.4
Time	6.2	6.7	3.9	4.2	4.5	5.1
Cost	9.6	10.5	6.1	6.5	7.0	7.8
Subtotal	15.8	17.2	10.0	10.8	11.5	12.9
Total	38.3	41.8	24.4	26.1	27.9	31.3
Upper (>$20K)						
Safety/Secur	3.9	3.9	3.1	3.5	3.9	4.3
Convenience	2.9	2.9	2.3	2.6	2.9	3.2
Comfort	3.7	3.7	3.0	3.3	3.7	4.1
Subtotal	10.5	10.5	8.4	9.5	10.5	11.6
Time	3.5	3.5	2.8	3.2	3.5	3.9
Cost	2.9	2.9	2.3	2.6	2.9	3.2
Subtotal	6.4	6.4	5.1	5.8	6.4	7.1
Total	16.9	16.9	13.5	15.2	16.9	18.6
TOTAL	62.2	65.7	43.1	46.6	50.0	56.9

Table 67--continued

LINE-HAUL WORTH (IN MILLIONS OF WORTH POINTS)

REGIONAL ENVIRONMENT A, MIX 3

	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
DUAL-MODE						
Poverty ($ 0 - 4K)						
Safety/Secur	.0	.0	.8	.8	.8	1.3
Convenience	.0	.0	.4	.4	.4	.5
Comfort	.0	.0	.6	.6	.6	.9
Subtotal	.0	.0	1.8	1.8	1.8	2.7
Time	.0	.0	.2	.2	.2	.3
Cost	.0	.0	2.1	2.1	2.1	3.2
Subtotal	.0	.0	2.3	2.3	2.3	3.5
Total	.0	.0	4.1	4.1	4.1	6.2
Lower ($ 4K - 10K)						
Safety/Secur	.0	.0	16.7	19.2	22.1	23.8
Convenience	.0	.0	14.2	16.3	18.8	20.2
Comfort	.0	.0	12.6	14.5	16.7	18.0
Subtotal	.0	.0	43.5	50.0	57.6	62.0
Time	.0	.0	8.5	9.8	11.3	12.1
Cost	.0	.0	27.6	31.7	36.5	39.3
Subtotal	.0	.0	36.1	41.5	47.8	51.4
Total	.0	.0	79.6	91.5	105.4	113.4
Middle ($ 10K - 20K)						
Safety/Secur	.0	.0	37.1	42.1	49.2	52.5
Convenience	.0	.0	39.4	44.7	52.3	55.8
Comfort	.0	.0	42.0	47.7	55.7	59.5
Subtotal	.0	.0	118.5	134.5	157.2	167.8
Time	.0	.0	22.7	25.8	30.1	32.1
Cost	.0	.0	40.9	46.5	54.3	58.0
Subtotal	.0	.0	63.6	72.2	84.4	90.1
Total	.0	.0	182.2	206.7	241.5	257.9
Upper (>$20K)						
Safety/Secur	.0	.0	8.3	9.2	10.8	11.7
Convenience	.0	.0	9.8	10.7	12.7	13.7
Comfort	.0	.0	9.4	10.4	12.3	13.2
Subtotal	.0	.0	27.5	30.3	35.8	38.6
Time	.0	.0	6.4	7.0	8.3	8.9
Cost	.0	.0	6.1	6.7	8.0	8.6
Subtotal	.0	.0	12.5	13.8	16.3	17.5
Total	.0	.0	40.0	44.0	52.1	56.1
TOTAL	.0	.0	305.9	346.4	403.1	433.4

GRAND TOTALS

	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
Poverty	24.5	26.6	30.8	32.8	36.9	41.0
Lower	191.0	207.0	246.9	269.6	297.7	321.7
Middle	162.3	172.7	283.5	316.7	358.3	386.7
Upper	30.0	31.6	60.1	65.8	77.1	84.5
GRAND TOTAL	407.8	437.9	621.3	684.8	770.1	833.8

Table 67--continued

LINE-HAUL WORTH (IN MILLIONS OF WORTH POINTS)

REGIONAL ENVIRONMENT B, MIX 1

	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
AUTO						
Poverty ($ 0 - 4K)						
Safety/Secur	1.8	2.1	2.5	2.5	2.9	3.6
Convenience	.5	.6	.8	.8	.9	1.1
Comfort	1.4	1.7	2.0	2.0	2.3	2.8
Subtotal	3.7	4.5	5.2	5.2	6.0	7.5
Time	.2	.2	.3	.3	.3	.4
Cost	6.6	7.9	9.2	9.2	10.6	13.2
Subtotal	6.8	8.1	9.5	9.5	10.9	13.6
Total	10.5	12.6	14.7	14.7	16.8	21.1
Lower ($ 4K - 10K)						
Safety/Secur	25.7	28.2	31.8	35.3	40.3	45.7
Convenience	15.6	17.1	19.2	21.4	24.4	27.6
Comfort	20.4	22.4	25.2	28.0	32.0	36.2
Subtotal	61.6	67.6	76.2	84.7	96.7	109.6
Time	6.8	7.5	8.5	9.4	10.7	12.2
Cost	61.1	67.1	75.6	84.1	95.9	108.7
Subtotal	68.0	74.6	84.0	93.5	106.7	120.8
Total	129.6	142.2	160.2	178.2	203.4	230.4
Middle ($ 10K - 20K)						
Safety/Secur	16.4	17.9	20.2	22.7	25.9	29.3
Convenience	12.4	13.5	15.3	17.1	19.6	22.2
Comfort	19.5	21.2	24.0	26.9	30.7	34.9
Subtotal	48.3	52.6	59.6	66.7	76.2	86.4
Time	5.2	5.7	6.5	7.2	8.3	9.4
Cost	26.0	28.3	32.1	35.9	41.0	46.5
Subtotal	31.3	34.0	38.6	43.2	49.3	55.9
Total	79.6	86.6	98.1	109.9	125.5	142.3
Upper (>$20K)						
Safety/Secur	1.4	1.8	2.1	2.1	2.5	2.9
Convenience	1.2	1.5	1.8	1.8	2.1	2.4
Comfort	1.7	2.1	2.5	2.5	3.0	3.4
Subtotal	4.3	5.4	6.5	6.5	7.5	8.6
Time	.6	.7	.9	.9	1.0	1.1
Cost	1.5	1.9	2.3	2.3	2.6	3.0
Subtotal	2.1	2.6	3.1	3.1	3.6	4.2
Total	6.4	8.0	9.6	9.6	11.2	12.8
TOTAL	226.1	249.4	282.7	312.4	356.9	406.5

LINE-HAUL WORTH (IN MILLIONS OF WORTH POINTS)

REGIONAL ENVIRONMENT B, MIX 1

	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
BUS						
Poverty ($ 0 - 4K)						
Safety/Secur	1.7	2.0	2.4	2.4	2.7	3.4
Convenience	.7	.8	1.0	1.0	1.1	1.4
Comfort	.8	1.0	1.1	1.1	1.3	1.6
Subtotal	3.2	3.8	4.4	4.4	5.1	6.4
Time	.2	.3	.3	.3	.3	.4
Cost	6.6	8.0	9.3	9.3	10.6	13.3
Subtotal	6.9	8.2	9.6	9.6	11.0	13.7
Total	10.0	12.0	14.0	14.0	16.0	20.1
Lower ($ 4K - 10K)						
Safety/Secur	6.0	6.7	7.4	8.4	9.7	10.8
Convenience	4.9	5.5	6.0	6.9	7.9	8.8
Comfort	2.9	3.2	3.6	4.1	4.7	5.2
Subtotal	13.9	15.4	17.0	19.3	22.4	24.7
Time	1.9	2.1	2.3	2.6	3.0	3.4
Cost	15.4	17.1	18.8	21.4	24.8	27.3
Subtotal	17.3	19.2	21.1	24.0	27.8	30.7
Total	31.2	34.6	38.1	43.3	50.2	55.4
Middle ($ 10K - 20K)						
Safety/Secur	3.0	3.0	3.7	4.0	4.7	5.0
Convenience	3.1	3.1	3.8	4.1	4.8	5.1
Comfort	2.2	2.2	2.7	2.9	3.4	3.7
Subtotal	8.3	8.3	10.1	11.1	12.9	13.8
Time	1.1	1.1	1.4	1.5	1.8	1.9
Cost	5.1	5.1	6.3	6.8	8.0	8.6
Subtotal	6.3	6.3	7.7	8.4	9.7	10.4
Total	14.6	14.6	17.8	19.4	22.7	24.3
Upper (>$20K)						
Safety/Secur	.0	.0	.0	.0	.0	.0
Convenience	.0	.0	.0	.0	.0	.0
Comfort	.0	.0	.0	.0	.0	.0
Subtotal	.0	.0	.0	.0	.0	.0
Time	.0	.0	.0	.0	.0	.0
Cost	.0	.0	.0	.0	.0	.0
Subtotal	.0	.0	.0	.0	.0	.0
Total	.0	.0	.0	.0	.0	.0
TOTAL	55.8	61.2	69.9	76.7	88.9	99.7

LINE-HAUL WORTH (IN MILLIONS OF WORTH POINTS)

REGIONAL ENVIRONMENT B, MIX 1

	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
RAIL						
Poverty ($ 0 - 4K)						
Safety/Secur	.7	.7	.7	.7	.7	.7
Convenience	.2	.2	.2	.2	.2	.2
Comfort	.5	.5	.5	.5	.5	.5
Subtotal	1.5	1.5	1.5	1.5	1.5	1.5
Time	.1	.1	.1	.1	.1	.1
Cost	2.4	2.4	2.4	2.4	2.4	2.4
Subtotal	2.5	2.5	2.5	2.5	2.5	2.5
Total	4.0	4.0	4.0	4.0	4.0	4.0
Lower ($ 4K - 10K)						
Safety/Secur	4.4	4.7	5.1	5.1	5.1	4.7
Convenience	2.8	3.1	3.3	3.3	3.3	3.1
Comfort	3.1	3.4	3.6	3.6	3.6	3.4
Subtotal	10.3	11.1	12.0	12.0	12.0	11.1
Time	2.0	2.2	2.4	2.4	2.4	2.2
Cost	9.1	9.9	10.7	10.7	10.7	9.9
Subtotal	11.2	12.1	13.0	13.0	13.0	12.1
Total	21.5	23.3	25.0	25.0	25.0	23.3
Middle ($ 10K - 20K)						
Safety/Secur	5.4	5.8	6.5	6.5	6.5	6.5
Convenience	4.4	4.7	5.3	5.3	5.3	5.3
Comfort	5.8	6.2	7.0	7.0	7.0	7.0
Subtotal	15.7	16.7	18.8	18.8	18.8	18.8
Time	3.1	3.3	3.7	3.7	3.7	3.7
Cost	7.6	8.1	9.1	9.1	9.1	9.1
Subtotal	10.7	11.4	12.8	12.8	12.8	12.8
Total	26.3	28.1	31.6	31.6	31.6	31.6
Upper (>$20K)						
Safety/Secur	1.8	1.8	1.8	1.8	1.8	1.8
Convenience	1.6	1.6	1.6	1.6	1.6	1.6
Comfort	1.9	1.9	1.9	1.9	1.9	1.9
Subtotal	5.4	5.4	5.4	5.4	5.4	5.4
Time	1.3	1.3	1.3	1.3	1.3	1.3
Cost	1.7	1.7	1.7	1.7	1.7	1.7
Subtotal	3.0	3.0	3.0	3.0	3.0	3.0
Total	8.3	8.3	8.3	8.3	8.3	8.3
TOTAL	60.1	63.7	69.0	69.0	69.0	67.2

LINE-HAUL WORTH (IN MILLIONS OF WORTH POINTS)

REGIONAL ENVIRONMENT B, MIX 1

	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
AIR						
Poverty ($ 0 - 4K)						
Safety/Secur	.0	.0	.0	.0	.0	.0
Convenience	.0	.0	.0	.0	.0	.0
Comfort	.0	.0	.0	.0	.0	.0
Subtotal	.0	.0	.0	.0	.0	.0
Time	.0	.0	.0	.0	.0	.0
Cost	.0	.0	.0	.0	.0	.0
Subtotal	.0	.0	.0	.0	.0	.0
Total	.0	.0	.0	.0	.0	.0
Lower ($ 4K - 10K)						
Safety/Secur	1.6	1.6	1.6	1.6	1.6	1.6
Convenience	.8	.8	.8	.8	.8	.8
Comfort	1.0	1.0	1.0	1.0	1.0	1.0
Subtotal	3.4	3.4	3.4	3.4	3.4	3.4
Time	.9	.9	.9	.9	.9	.9
Cost	2.6	2.6	2.6	2.6	2.6	2.6
Subtotal	3.6	3.6	3.6	3.6	3.6	3.6
Total	7.0	7.0	7.0	7.0	7.0	7.0
Middle ($ 10K - 20K)						
Safety/Secur	8.2	9.0	9.4	10.1	10.1	9.4
Convenience	5.5	6.0	6.3	6.8	6.8	6.3
Comfort	7.8	8.5	8.9	9.6	9.6	8.9
Subtotal	21.5	23.6	24.6	26.6	26.6	24.6
Time	5.9	6.5	6.7	7.3	7.3	6.7
Cost	9.2	10.0	10.5	11.3	11.3	10.5
Subtotal	15.1	16.5	17.2	18.6	18.6	17.2
Total	36.6	40.0	41.8	45.3	45.3	41.8
Upper (>$20K)						
Safety/Secur	3.9	3.9	4.3	4.3	4.7	4.3
Convenience	2.9	2.9	3.2	3.2	3.5	3.2
Comfort	3.7	3.7	4.1	4.1	4.5	4.1
Subtotal	10.5	10.5	11.6	11.6	12.6	11.6
Time	3.5	3.5	3.9	3.9	4.2	3.9
Cost	2.9	2.9	3.2	3.2	3.5	3.2
Subtotal	6.4	6.4	7.1	7.1	7.7	7.1
Total	16.9	16.9	18.6	18.6	20.3	18.6
TOTAL	60.4	63.9	67.4	70.8	72.5	67.4

REGIONAL ENVIRONMENT B, MIX 1

GRAND TOTALS

	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
Poverty	24.4	28.7	32.8	32.8	36.9	45.1
Lower	189.2	207.0	230.3	253.5	285.6	316.0
Middle	157.1	169.3	189.3	206.2	225.0	240.0
Upper	31.7	33.3	36.6	36.6	39.8	39.7
GRAND TOTAL	402.5	438.2	488.9	529.0	587.3	640.8

Table 67--continued

LINE-HAUL WORTH (IN MILLIONS OF WORTH POINTS)

REGIONAL ENVIRONMENT B, MIX 2

	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
AUTO						
Poverty ($ 0 - 4K)						
Safety/Secur	1.9	2.1	2.5	2.7	3.1	3.6
Convenience	.6	.6	.7	.8	1.0	1.1
Comfort	1.5	1.7	2.0	2.2	2.5	2.8
Subtotal	4.0	4.4	5.2	5.8	6.6	7.5
Time	.2	.2	.3	.3	.3	.4
Cost	7.1	7.8	9.1	10.2	11.6	13.2
Subtotal	7.3	8.0	9.4	10.5	12.0	13.6
Total	11.4	12.4	14.5	16.2	18.5	21.1
Lower ($ 4K - 10K)						
Safety/Secur	25.7	28.1	30.8	34.5	39.4	44.8
Convenience	15.6	17.0	18.7	20.9	23.8	27.1
Comfort	20.4	22.3	24.5	27.3	31.2	35.5
Subtotal	61.6	67.4	74.0	82.7	94.5	107.3
Time	6.8	7.5	8.2	9.2	10.5	11.9
Cost	61.1	66.8	73.4	82.0	93.7	106.5
Subtotal	68.0	74.3	81.6	91.2	104.2	118.4
Total	129.6	141.7	155.5	173.9	198.7	225.7
Middle ($ 10K - 20K)						
Safety/Secur	16.5	18.0	14.8	16.6	19.1	21.5
Convenience	12.4	13.6	11.2	12.5	14.5	16.3
Comfort	19.5	21.4	17.6	19.7	22.7	25.5
Subtotal	48.5	53.0	43.6	48.8	56.3	63.3
Time	5.3	5.7	4.7	5.3	6.1	6.8
Cost	26.1	28.5	23.5	26.3	30.3	34.1
Subtotal	31.3	34.3	28.2	31.6	36.4	40.8
Total	79.8	87.2	71.8	80.3	92.8	104.2
Upper (>$20K)						
Safety/Secur	1.5	1.7	1.2	1.4	1.6	1.8
Convenience	1.3	1.4	1.0	1.2	1.3	1.5
Comfort	1.8	2.0	1.5	1.7	1.9	2.1
Subtotal	4.6	5.1	3.8	4.2	4.7	5.4
Time	.6	.7	.5	.6	.6	.7
Cost	1.6	1.8	1.3	1.5	1.7	1.9
Subtotal	2.2	2.4	1.8	2.0	2.3	2.6
Total	6.9	7.5	5.6	6.2	7.0	8.0
TOTAL	227.6	248.8	247.5	276.6	317.1	359.9

LINE-HAUL WORTH (IN MILLIONS OF WORTH POINTS)

REGIONAL ENVIRONMENT B, MIX 2

	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
BUS						
Poverty ($ 0 - 4K)						
Safety/Secur	1.8	2.0	2.3	2.6	3.0	3.4
Convenience	.7	.8	.9	1.1	1.2	1.4
Comfort	.9	1.0	1.1	1.2	1.4	1.6
Subtotal	3.4	3.7	4.4	4.9	5.6	6.4
Time	.2	.2	.3	.3	.4	.4
Cost	7.2	7.8	9.2	10.2	11.7	13.3
Subtotal	7.4	8.1	9.5	10.6	12.1	13.7
Total	10.8	11.8	13.8	15.4	17.7	20.1
Lower ($ 4K - 10K)						
Safety/Secur	6.1	6.7	7.3	8.1	9.3	10.6
Convenience	5.0	5.4	5.9	6.6	7.6	8.6
Comfort	2.9	3.2	3.5	3.9	4.5	5.1
Subtotal	14.1	15.3	16.7	18.7	21.3	24.2
Time	1.9	2.1	2.3	2.5	2.9	3.3
Cost	15.5	16.9	18.4	20.7	23.6	26.8
Subtotal	17.5	19.0	20.7	23.2	26.5	30.1
Total	31.5	34.3	37.4	41.9	47.8	54.4
Middle ($ 10K - 20K)						
Safety/Secur	2.9	3.2	3.1	3.5	4.0	4.5
Convenience	2.9	3.2	3.1	3.5	4.0	4.6
Comfort	2.1	2.3	2.2	2.5	2.9	3.3
Subtotal	7.9	8.7	8.5	9.5	10.9	12.4
Time	1.1	1.2	1.2	1.3	1.5	1.7
Cost	4.9	5.4	5.2	5.9	6.7	7.6
Subtotal	6.0	6.5	6.4	7.2	8.2	9.3
Total	13.9	15.2	14.9	16.7	19.1	21.7
Upper (>$20K)						
Safety/Secur	.0	.0	.0	.0	.0	.0
Convenience	.0	.0	.0	.0	.0	.0
Comfort	.0	.0	.0	.0	.0	.0
Subtotal	.0	.0	.0	.0	.0	.0
Time	.0	.0	.0	.0	.0	.0
Cost	.0	.0	.0	.0	.0	.0
Subtotal	.0	.0	.0	.0	.0	.0
Total	.0	.0	.0	.0	.0	.0
TOTAL	56.3	61.3	66.1	74.0	84.5	96.1

LINE-HAUL WORTH (IN MILLIONS OF WORTH POINTS)

REGIONAL ENVIRONMENT B, MIX 2

	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
RAIL						
Poverty ($ 0 - 4K)						
Safety/Secur	.6	.6	.0	.0	.0	.0
Convenience	.2	.2	.0	.0	.0	.0
Comfort	.4	.4	.0	.0	.0	.0
Subtotal	1.2	1.3	.0	.0	.0	.0
Time	.1	.1	.0	.0	.0	.0
Cost	1.9	2.0	.0	.0	.0	.0
Subtotal	2.0	2.1	.0	.0	.0	.0
Total	3.2	3.4	.0	.0	.0	.0
Lower ($ 4K - 10K)						
Safety/Secur	4.4	4.7	.0	.0	.0	.0
Convenience	2.8	3.0	.0	.0	.0	.0
Comfort	3.1	3.3	.0	.0	.0	.0
Subtotal	10.3	11.1	.0	.0	.0	.0
Time	2.0	2.2	.0	.0	.0	.0
Cost	9.1	9.8	.0	.0	.0	.0
Subtotal	11.2	12.0	.0	.0	.0	.0
Total	21.5	23.1	.0	.0	.0	.0
Middle ($ 10K - 20K)						
Safety/Secur	5.6	6.0	.0	.0	.0	.0
Convenience	4.5	4.8	.0	.0	.0	.0
Comfort	5.9	6.4	.0	.0	.0	.0
Subtotal	16.0	17.2	.0	.0	.0	.0
Time	3.1	3.4	.0	.0	.0	.0
Cost	7.8	8.4	.0	.0	.0	.0
Subtotal	10.9	11.7	.0	.0	.0	.0
Total	26.9	29.0	.0	.0	.0	.0
Upper (>$20K)						
Safety/Secur	1.4	1.5	.0	.0	.0	.0
Convenience	1.2	1.3	.0	.0	.0	.0
Comfort	1.5	1.6	.0	.0	.0	.0
Subtotal	4.1	4.4	.0	.0	.0	.0
Time	1.0	1.0	.0	.0	.0	.0
Cost	1.3	1.4	.0	.0	.0	.0
Subtotal	2.3	2.4	.0	.0	.0	.0
Total	6.3	6.8	.0	.0	.0	.0
TOTAL	57.9	62.3	.0	.0	.0	.0

LINE-HAUL WORTH (IN MILLIONS OF WORTH POINTS)

REGIONAL ENVIRONMENT B, MIX 2

	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
AIR						
Poverty ($ 0 - 4K)						
Safety/Secur	.0	.0	.0	.0	.0	.0
Convenience	.0	.0	.0	.0	.0	.0
Comfort	.0	.0	.0	.0	.0	.0
Subtotal	.0	.0	.0	.0	.0	.0
Time	.0	.0	.0	.0	.0	.0
Cost	.0	.0	.0	.0	.0	.0
Subtotal	.0	.0	.0	.0	.0	.0
Total	.0	.0	.0	.0	.0	.0
Lower ($ 4K - 10K)						
Safety/Secur	1.4	1.5	.5	.5	.6	.5
Convenience	.8	.8	.3	.3	.3	.3
Comfort	.9	1.0	.3	.3	.4	.3
Subtotal	3.1	3.3	1.2	1.2	1.3	1.2
Time	.8	.9	.3	.3	.4	.3
Cost	2.4	2.6	.9	.9	1.0	.9
Subtotal	3.2	3.5	1.2	1.2	1.3	1.2
Total	6.3	6.8	2.4	2.4	2.6	2.4
Middle ($ 10K - 20K)						
Safety/Secur	8.3	9.0	3.4	3.6	3.7	3.4
Convenience	5.6	6.1	2.3	2.4	2.5	2.3
Comfort	7.9	8.6	3.3	3.5	3.5	3.3
Subtotal	21.8	23.7	9.0	9.5	9.6	9.0
Time	6.0	6.5	2.5	2.6	2.6	2.5
Cost	9.3	10.1	3.8	4.1	4.1	3.8
Subtotal	15.3	16.6	6.3	6.7	6.7	6.3
Total	37.1	40.2	15.3	16.2	16.4	15.3
Upper (>$20K)						
Safety/Secur	3.7	4.0	2.4	2.5	2.6	2.4
Convenience	2.7	3.0	1.8	1.9	1.9	1.8
Comfort	3.5	3.8	2.3	2.4	2.4	2.3
Subtotal	9.9	10.7	6.5	6.8	6.9	6.5
Time	3.3	3.6	2.2	2.3	2.3	2.2
Cost	2.7	3.0	1.8	1.9	1.9	1.8
Subtotal	6.0	6.5	4.0	4.2	4.2	4.0
Total	15.9	17.3	10.5	11.0	11.2	10.5
TOTAL	59.3	64.3	28.3	29.6	30.1	28.3

Table 67--continued

LINE-HAUL WORTH (IN MILLIONS OF WORTH POINTS)

REGIONAL ENVIRONMENT B, MIX 2

	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
TACV						
Poverty ($ 0 - 4K)						
Safety/Secur	.0	.0	.4	.5	.5	.6
Convenience	.0	.0	.1	.1	.2	.2
Comfort	.0	.0	.4	.4	.4	.5
Subtotal	.0	.0	.9	1.0	1.1	1.2
Time	.0	.0	.0	.0	.0	.0
Cost	.0	.0	1.1	1.2	1.3	1.4
Subtotal	.0	.0	1.1	1.3	1.4	1.5
Total	.0	.0	2.1	2.3	2.4	2.6
Lower ($ 4K - 10K)						
Safety/Secur	.0	.0	9.0	9.8	10.7	10.7
Convenience	.0	.0	5.4	5.9	6.4	6.4
Comfort	.0	.0	7.4	8.1	8.8	8.8
Subtotal	.0	.0	21.7	23.8	25.8	25.9
Time	.0	.0	5.6	6.1	6.6	6.7
Cost	.0	.0	14.9	16.4	17.8	17.8
Subtotal	.0	.0	20.5	22.5	24.4	24.5
Total	.0	.0	42.2	46.3	50.2	50.3
Middle ($ 10K - 20K)						
Safety/Secur	.0	.0	28.7	31.4	34.5	34.2
Convenience	.0	.0	21.4	23.4	25.7	25.5
Comfort	.0	.0	35.3	38.7	42.4	42.2
Subtotal	.0	.0	85.4	93.6	102.6	101.9
Time	.0	.0	21.5	23.6	25.9	25.7
Cost	.0	.0	31.8	34.9	38.2	38.0
Subtotal	.0	.0	53.4	58.5	64.1	63.7
Total	.0	.0	138.8	152.1	166.7	165.6
Upper (>$20K)						
Safety/Secur	.0	.0	7.2	10.8	8.6	8.5
Convenience	.0	.0	5.9	8.9	7.1	7.0
Comfort	.0	.0	8.8	13.3	10.6	10.5
Subtotal	.0	.0	21.8	33.0	26.3	26.0
Time	.0	.0	5.7	10.1	8.1	8.0
Cost	.0	.0	5.3	8.0	6.4	6.3
Subtotal	.0	.0	12.0	18.2	14.5	14.3
Total	.0	.0	33.9	51.2	40.7	40.4
TOTAL	.0	.0	216.9	251.8	260.1	258.9

LINE-HAUL WORTH (IN MILLIONS OF WORTH POINTS)

REGIONAL ENVIRONMENT B, MIX 2

	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
STOL						
Poverty ($ 0 - 4K)						
Safety/Secur	.0	.0	.0	.0	.2	.3
Convenience	.0	.0	.0	.0	.1	.1
Comfort	.0	.0	.0	.0	.1	.2
Subtotal	.0	.0	.0	.1	.4	.5
Time	.0	.0	.0	.0	.0	.1
Cost	.0	.0	.0	.1	.4	.6
Subtotal	.0	.0	.0	.1	.5	.7
Total	.0	.0	.0	.2	.9	1.2
Lower ($ 4K - 10K)						
Safety/Secur	.0	.0	.0	.6	3.7	5.6
Convenience	.0	.0	.0	.3	2.0	3.1
Comfort	.0	.0	.0	.4	2.4	3.6
Subtotal	.0	.0	.0	1.3	8.2	12.3
Time	.0	.0	.0	.4	2.2	3.4
Cost	.0	.0	.0	.9	5.3	8.0
Subtotal	.0	.0	.0	1.2	7.6	11.4
Total	.0	.0	.0	2.6	15.8	23.7
Middle ($ 10K - 20K)						
Safety/Secur	.0	.0	.0	2.0	11.6	18.0
Convenience	.0	.0	.0	1.3	7.9	12.3
Comfort	.0	.0	.0	1.9	11.2	17.3
Subtotal	.0	.0	.0	5.2	30.7	47.6
Time	.0	.0	.0	1.4	8.3	12.9
Cost	.0	.0	.0	1.9	11.0	17.1
Subtotal	.0	.0	.0	3.3	19.4	30.1
Total	.0	.0	.0	8.5	50.1	77.7
Upper (>$20K)						
Safety/Secur	.0	.0	.0	.7	2.9	4.5
Convenience	.0	.0	.0	.5	2.2	3.4
Comfort	.0	.0	.0	.7	2.8	4.3
Subtotal	.0	.0	.0	1.9	7.8	12.2
Time	.0	.0	.0	.6	2.6	4.0
Cost	.0	.0	.0	.4	1.8	2.9
Subtotal	.0	.0	.0	1.1	4.4	6.9
Total	.0	.0	.0	2.9	12.3	19.2
TOTAL	.0	.0	.0	14.2	78.9	121.7

GRAND TOTALS

REGIONAL ENVIRONMENT B, MIX 2

	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
Poverty	25.4	27.6	30.4	34.1	39.5	44.9
Lower	188.8	205.8	237.5	267.1	315.0	356.6
Middle	157.7	171.6	240.8	273.7	345.0	384.4
Upper	29.1	31.6	49.9	71.3	71.2	78.0
GRAND TOTAL	401.0	436.7	558.7	646.2	770.7	863.9

Table 67--continued

LINE-HAUL WORTH (IN MILLIONS OF WORTH POINTS)

REGIONAL ENVIRONMENT B, MIX 3

	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
AUTO						
Poverty ($ 0 - 4K)						
Safety/Secur	1.9	2.1	2.1	2.3	2.6	3.0
Convenience	.6	.6	.6	.7	.8	.9
Comfort	1.5	1.7	1.6	1.8	2.1	2.4
Subtotal	4.0	4.4	4.3	4.8	5.5	6.3
Time	.2	.2	.2	.2	.3	.3
Cost	7.1	7.8	7.7	8.4	9.8	11.1
Subtotal	7.3	8.0	7.9	8.7	10.0	11.4
Total	11.4	12.4	12.2	13.5	15.6	17.7
Lower ($ 4K - 10K)						
Safety/Secur	25.7	28.1	20.6	23.0	26.3	29.8
Convenience	15.6	17.0	12.4	13.9	15.9	18.1
Comfort	20.4	22.3	16.3	18.2	20.8	23.7
Subtotal	61.6	67.4	49.3	55.1	63.0	71.6
Time	6.8	7.5	5.5	6.1	7.0	7.9
Cost	61.1	66.8	48.9	54.7	62.5	71.0
Subtotal	68.0	74.3	54.4	60.8	69.5	78.9
Total	129.6	141.7	103.7	115.9	132.5	150.5
Middle ($ 10K - 20K)						
Safety/Secur	16.5	18.0	9.9	11.0	12.6	14.3
Convenience	12.4	13.6	7.5	8.3	9.5	10.8
Comfort	19.5	21.4	11.7	13.1	15.0	17.0
Subtotal	48.5	53.0	29.0	32.5	37.1	42.1
Time	5.3	5.7	3.1	3.5	4.0	4.6
Cost	26.1	28.5	15.6	17.5	20.0	22.7
Subtotal	31.3	34.3	18.8	21.0	24.0	27.3
Total	79.8	87.2	47.8	53.5	61.1	69.4
Upper (>$20K)						
Safety/Secur	1.5	1.7	.8	.9	1.0	1.2
Convenience	1.3	1.4	.7	.8	.9	1.0
Comfort	1.8	2.0	1.0	1.1	1.2	1.4
Subtotal	4.6	5.1	2.5	2.8	3.1	3.6
Time	.6	.7	.3	.4	.4	.5
Cost	1.6	1.8	.9	1.0	1.1	1.2
Subtotal	2.2	2.4	1.2	1.4	1.5	1.7
Total	6.9	7.5	3.7	4.2	4.6	5.3
TOTAL	227.6	248.8	167.3	187.0	213.1	242.9

LINE-HAUL WORTH (IN MILLIONS OF WORTH POINTS)

REGIONAL ENVIRONMENT B, MIX 3

	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
BUS						
Poverty ($ 0 - 4K)						
Safety/Secur	1.8	2.0	2.2	2.5	2.9	3.2
Convenience	.7	.8	.9	1.0	1.2	1.3
Comfort	.9	1.0	1.1	1.2	1.4	1.6
Subtotal	3.4	3.7	4.2	4.7	5.4	6.1
Time	.2	.2	.3	.3	.4	.4
Cost	7.2	7.8	8.8	9.8	11.3	12.8
Subtotal	7.4	8.1	9.0	10.1	11.7	13.2
Total	10.8	11.8	13.2	14.8	17.1	19.3
Lower ($ 4K - 10K)						
Safety/Secur	6.1	6.7	7.5	8.4	9.6	10.9
Convenience	5.0	5.4	6.1	6.9	7.8	8.9
Comfort	2.9	3.2	3.6	4.1	4.6	5.2
Subtotal	14.1	15.3	17.2	19.3	22.0	25.0
Time	1.9	2.1	2.3	2.6	3.0	3.4
Cost	15.5	16.9	19.0	21.4	24.3	27.7
Subtotal	17.5	19.0	21.4	24.0	27.3	31.1
Total	31.5	34.3	38.6	43.3	49.3	56.1
Middle ($ 10K - 20K)						
Safety/Secur	2.9	3.3	3.6	4.0	4.5	5.2
Convenience	2.9	3.4	3.6	4.0	4.6	5.3
Comfort	2.1	2.4	2.6	2.9	3.3	3.8
Subtotal	7.9	9.1	9.8	10.9	12.4	14.2
Time	1.1	1.2	1.3	1.5	1.7	1.9
Cost	4.9	5.6	6.0	6.7	7.6	8.8
Subtotal	6.0	6.9	7.4	8.2	9.3	10.7
Total	13.9	16.0	17.2	19.1	21.7	24.9
Upper (>$20K)						
Safety/Secur	.0	.0	.0	.0	.0	.0
Convenience	.0	.0	.0	.0	.0	.0
Comfort	.0	.0	.0	.0	.0	.0
Subtotal	.0	.0	.0	.0	.0	.0
Time	.0	.0	.0	.0	.0	.0
Cost	.0	.0	.0	.0	.0	.0
Subtotal	.0	.0	.0	.0	.0	.0
Total	.0	.0	.0	.0	.0	.0
TOTAL	56.3	62.1	69.0	77.2	88.1	100.3

LINE-HAUL WORTH (IN MILLIONS OF WORTH POINTS)

REGIONAL ENVIRONMENT B, MIX 3

	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
RAIL						
Poverty ($ 0 - 4K)						
Safety/Secur	.6	.6	.4	.5	.5	.4
Convenience	.2	.2	.1	.2	.2	.1
Comfort	.4	.4	.3	.3	.3	.3
Subtotal	1.2	1.3	.9	1.0	1.0	.9
Time	.1	.1	.1	.1	.1	.1
Cost	1.9	2.0	1.4	1.5	1.5	1.4
Subtotal	2.0	2.1	1.5	1.6	1.6	1.5
Total	3.2	3.4	2.4	2.6	2.6	2.4
Lower ($ 4K - 10K)						
Safety/Secur	4.4	4.7	4.3	4.5	4.6	4.3
Convenience	2.8	3.0	2.8	2.9	3.0	2.8
Comfort	3.1	3.3	3.1	3.2	3.3	3.1
Subtotal	10.3	11.1	10.2	10.7	10.8	10.2
Time	2.0	2.2	2.0	2.1	2.1	2.0
Cost	9.1	9.8	9.1	9.5	9.6	9.1
Subtotal	11.2	12.0	11.1	11.7	11.7	11.1
Total	21.5	23.1	21.3	22.4	22.5	21.3
Middle ($ 10K - 20K)						
Safety/Secur	5.6	6.0	2.8	2.9	2.9	2.8
Convenience	4.5	4.8	2.2	2.3	2.4	2.2
Comfort	5.9	6.4	2.9	3.1	3.1	2.9
Subtotal	16.0	17.2	7.9	8.4	8.5	7.9
Time	3.1	3.4	1.6	1.6	1.7	1.6
Cost	7.8	8.4	3.9	4.1	4.1	3.9
Subtotal	10.9	11.7	5.4	5.7	5.8	5.4
Total	26.9	29.0	13.3	14.0	14.2	13.3
Upper (>$20K)						
Safety/Secur	1.4	1.5	.5	.5	.5	.5
Convenience	1.2	1.3	.5	.5	.5	.5
Comfort	1.5	1.6	.5	.6	.6	.5
Subtotal	4.1	4.4	1.5	1.6	1.6	1.5
Time	1.0	1.0	.4	.4	.4	.4
Cost	1.3	1.4	.5	.5	.5	.5
Subtotal	2.3	2.4	.8	.9	.9	.8
Total	6.3	6.8	2.3	2.5	2.5	2.3
TOTAL	57.9	62.3	39.4	41.5	41.9	39.4

LINE-HAUL WORTH (IN MILLIONS OF WORTH POINTS)

REGIONAL ENVIRONMENT B, MIX 3

	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
AIR						
Poverty ($ 0 - 4K)						
Safety/Secur	.0	.0	.0	.0	.0	.0
Convenience	.0	.0	.0	.0	.0	.0
Comfort	.0	.0	.0	.0	.0	.0
Subtotal	.0	.0	.0	.0	.0	.0
Time	.0	.0	.0	.0	.0	.0
Cost	.0	.0	.0	.0	.0	.0
Subtotal	.0	.0	.0	.0	.0	.0
Total	.0	.0	.0	.0	.0	.0
Lower ($ 4K - 10K)						
Safety/Secur	1.4	1.5	1.1	1.1	1.2	1.1
Convenience	.8	.8	.6	.6	.6	.6
Comfort	.9	1.0	.7	.7	.7	.7
Subtotal	3.1	3.3	2.4	2.5	2.5	2.4
Time	.8	.9	.7	.7	.7	.7
Cost	2.4	2.6	1.8	1.9	2.0	1.8
Subtotal	3.2	3.5	2.5	2.6	2.7	2.5
Total	6.3	6.8	4.9	5.0	5.2	4.9
Middle ($ 10K - 20K)						
Safety/Secur	8.3	9.0	5.1	5.4	5.5	5.1
Convenience	5.6	6.1	3.5	3.7	3.7	3.5
Comfort	7.9	8.6	4.9	5.2	5.3	4.9
Subtotal	21.8	23.7	13.5	14.2	14.5	13.5
Time	6.0	6.5	3.7	3.9	4.0	3.7
Cost	9.3	10.1	5.8	6.1	6.2	5.8
Subtotal	15.3	16.6	9.5	10.0	10.2	9.5
Total	37.1	40.2	23.0	24.2	24.7	23.0
Upper (>$20K)						
Safety/Secur	3.7	4.0	3.1	3.3	3.3	3.1
Convenience	2.7	3.0	2.3	2.4	2.5	2.3
Comfort	3.5	3.8	2.9	3.1	3.2	2.9
Subtotal	9.9	10.7	8.3	8.8	8.9	8.3
Time	3.3	3.6	2.8	2.9	3.0	2.8
Cost	2.7	3.0	2.3	2.4	2.5	2.3
Subtotal	6.0	6.5	5.1	5.4	5.5	5.1
Total	15.9	17.3	13.4	14.2	14.4	13.4
TOTAL	59.3	64.3	41.2	43.5	44.3	41.2

Table 67--continued

LINE-HAUL WORTH (IN MILLIONS OF WORTH POINTS)

REGIONAL ENVIRONMENT B, MIX 3

	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
DUAL-MODE						
Poverty ($ 0 - 4K)						
Safety/Secur	.0	.0	.7	.8	1.2	1.3
Convenience	.0	.0	.3	.4	.5	.5
Comfort	.0	.0	.5	.6	.9	1.0
Subtotal	.0	.0	1.5	1.8	2.5	2.8
Time	.0	.0	.1	.2	.2	.3
Cost	.0	.0	1.8	2.1	3.0	3.3
Subtotal	.0	.0	2.0	2.3	3.2	3.6
Total	.0	.0	3.5	4.1	5.8	6.4
Lower ($ 4K - 10K)						
Safety/Secur	.0	.0	15.5	18.1	24.9	28.4
Convenience	.0	.0	13.2	15.4	21.2	24.1
Comfort	.0	.0	11.7	13.6	18.8	21.4
Subtotal	.0	.0	40.3	47.1	65.0	73.9
Time	.0	.0	7.9	9.2	12.7	14.5
Cost	.0	.0	25.6	29.8	41.2	46.9
Subtotal	.0	.0	33.5	39.1	53.9	61.3
Total	.0	.0	73.8	86.1	118.9	135.3
Middle ($ 10K - 20K)						
Safety/Secur	.0	.0	34.2	39.9	55.3	62.8
Convenience	.0	.0	36.3	42.4	58.7	66.7
Comfort	.0	.0	38.7	45.2	62.5	71.0
Subtotal	.0	.0	109.2	127.6	176.5	200.5
Time	.0	.0	20.9	24.4	33.8	38.4
Cost	.0	.0	37.7	44.1	61.0	69.2
Subtotal	.0	.0	58.6	68.5	94.7	107.6
Total	.0	.0	167.9	196.1	271.2	308.1
Upper (>$20K)						
Safety/Secur	.0	.0	7.6	8.9	12.3	13.9
Convenience	.0	.0	8.9	10.4	14.3	16.3
Comfort	.0	.0	8.6	10.1	13.9	15.8
Subtotal	.0	.0	25.1	29.3	40.5	46.0
Time	.0	.0	5.8	6.8	9.4	10.7
Cost	.0	.0	5.6	6.5	9.0	10.2
Subtotal	.0	.0	11.4	13.3	18.4	20.9
Total	.0	.0	36.4	42.6	58.9	66.9
TOTAL	.0	.0	281.6	329.0	454.8	516.6

GRAND TOTALS

REGIONAL ENVIRONMENT B, MIX ..

	1970-75	1975-80	1980-85	1985-90	1990-95	1995-2000
Poverty	25.4	27.6	31.4	35.0	41.0	45.7
Lower	188.8	205.8	242.2	272.7	328.5	368.0
Middle	157.7	172.5	269.1	306.9	393.0	438.7
Upper	29.1	31.6	55.8	63.5	80.4	87.9
GRAND TOTAL	401.0	437.5	598.5	678.2	842.9	940.3

Table 68

SAMPLE OUTPUT: ANALYSIS OF SOCIETAL BENEFITS

(Five-year Indices)

	Regional Environment A, Mix 1						Regional Environment A, Mix 2						Regional Environment A, Mix 3					
	1970-75	1975-80	1980-85	1985-90	1990-95	1995-00	1970-75	1975-80	1980-85	1985-90	1990-95	1995-00	1970-75	1975-80	1980-85	1985-90	1990-95	1995-00
Human Physiology																		
Air Pollution	12.2	13.2	14.2	15.3	16.5	17.9	12.2	13.2	14.2	15.4	16.8	18.1	12.2	13.2	14.3	15.6	16.9	18.2
Noise Pollution	7.5	8.1	8.8	9.5	10.2	11.0	7.5	8.1	8.7	9.4	10.0	10.8	7.5	8.1	8.8	10.5	11.3	12.2
Acc to Non-User	13.8	14.9	16.1	17.4	18.8	20.3	13.8	14.9	16.1	17.5	19.0	20.5	13.8	14.9	16.2	17.7	19.3	20.8
Subtotal:	33.5	36.2	39.0	42.2	45.6	49.1	33.5	36.2	39.0	42.3	45.8	49.4	33.5	36.2	39.3	43.8	47.5	51.2
Right-of-Way Associated																		
Partitioning	1.2	1.3	1.4	1.5	1.6	1.7	1.2	1.3	1.4	1.4	1.5	1.6	1.2	1.3	1.2	1.2	1.3	1.4
Displacement	2.3	2.5	2.7	2.9	3.1	3.4	2.3	2.5	2.7	2.9	3.1	3.4	2.3	2.5	2.4	2.6	2.8	3.0
Constr Incon	2.2	2.4	2.6	2.8	3.0	3.2	2.2	2.4	2.6	2.8	3.0	3.2	2.2	2.4	2.0	2.2	2.4	2.6
Proprty Values	1.9	2.0	2.2	2.4	2.5	2.7	1.9	2.0	2.2	2.4	2.6	2.8	1.9	2.0	1.9	2.0	2.2	2.4
Subtotal:	7.5	8.1	8.8	9.5	10.2	11.1	7.5	8.1	8.8	9.5	10.2	11.0	7.5	8.1	7.4	8.1	8.7	9.4
Economic																		
Employment	6.9	7.4	8.0	8.7	9.4	10.2	6.9	7.4	8.1	8.9	9.6	10.3	6.9	7.4	7.9	8.5	9.3	10.0
Personal Income	9.5	10.3	11.1	12.0	13.0	14.1	9.5	10.3	11.2	12.2	13.2	14.3	9.5	10.3	11.1	12.0	13.0	14.1
Indus Dist	1.6	1.7	1.9	2.0	2.2	2.4	1.6	1.7	1.9	2.0	2.2	2.4	1.6	1.7	1.9	2.0	2.2	2.4
Pop Dist	.4	.4	.5	.5	.5	.6	.4	.4	.5	.5	.6	.6	.4	.4	.5	.5	.6	.6
Subtotal:	18.3	19.8	21.5	23.3	25.1	27.2	18.3	19.8	21.7	23.6	25.6	27.6	18.3	19.8	21.3	23.1	25.1	27.1
Metropolitan Form and Design																		
Land Use Dist	.7	.8	.9	.9	1.0	1.1	.7	.8	1.4	1.6	1.9	2.1	.7	.8	1.0	1.0	1.1	1.2
Housing	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Metro Design	1.9	2.1	2.2	2.4	2.6	2.8	1.9	2.1	2.5	2.7	2.9	3.1	1.9	2.1	2.7	2.9	3.2	3.5
Subtotal:	2.7	2.9	3.1	3.3	3.6	3.9	2.7	2.9	3.9	4.3	4.8	5.2	2.7	2.9	3.6	4.0	4.3	4.7
Sociological-Political																		
Ind Life Style	7.3	7.9	8.5	9.2	10.0	10.8	7.3	7.9	8.9	9.7	10.5	11.3	7.3	7.9	9.7	10.6	11.6	12.6
Commty Involvmt	4.0	4.3	4.7	5.0	5.4	5.9	4.0	4.3	4.8	5.2	5.6	6.1	4.0	4.3	5.1	5.6	6.1	6.6
Government Form	1.6	1.7	1.8	2.0	2.1	2.3	1.6	1.7	2.0	2.2	2.4	2.5	1.6	1.7	1.8	2.0	2.1	2.3
Tax Policy	1.0	1.0	1.1	1.2	1.3	1.4	1.0	1.0	1.3	1.4	1.6	1.7	1.0	1.0	1.7	1.9	2.1	2.2
Govt Services	3.3	3.6	3.7	4.0	4.3	4.7	3.3	3.6	3.9	4.3	4.7	5.1	3.3	3.6	4.7	5.0	5.3	5.8
Subtotal:	17.2	18.6	19.8	21.5	23.2	25.0	17.2	18.6	20.9	22.8	24.8	26.7	17.2	18.6	23.0	25.1	27.2	29.5
Scarce Resources																		
Radio Reception	2.3	2.5	2.7	2.9	3.2	3.4	2.3	2.5	2.7	2.9	3.2	3.4	2.3	2.5	2.7	2.9	3.2	3.4
Elec Power Cap	2.6	2.8	3.0	3.3	3.6	3.8	2.6	2.8	2.7	2.6	2.5	2.7	2.6	2.8	2.7	2.6	2.5	2.7
Ecology	1.8	2.0	2.1	2.3	2.5	2.7	1.8	2.0	3.2	3.5	5.0	5.4	1.8	2.0	3.2	3.5	5.0	5.4
Subtotal:	6.8	7.3	7.9	8.5	9.2	10.0	6.8	7.3	8.6	9.0	10.7	11.5	6.8	7.3	8.7	9.1	10.7	11.5
GRAND TOTAL:	86.0	93.0	100.1	108.3	116.9	126.2	86.0	93.0	102.9	111.5	121.9	131.4	86.0	93.0	103.3	113.2	123.5	133.4

Table 68--continued

	Regional Environment B, Mix 1						Regional Environment B, Mix 2						Regional Environment B, Mix 3					
	1970-75	1975-80	1980-85	1985-90	1990-95	1995-00	1970-75	1975-80	1980-85	1985-90	1990-95	1995-00	1970-75	1975-80	1980-85	1985-90	1990-95	1995-00
Human Physiology																		
Air Pollution	11.8	13.1	13.9	14.8	16.3	18.8	11.8	13.1	13.9	14.9	16.5	19.1	11.8	13.1	14.0	15.0	16.6	19.2
Noise Pollution	7.4	8.2	8.8	9.7	11.1	13.4	7.4	8.2	8.8	9.4	10.1	11.8	7.4	8.2	8.9	10.5	12.0	14.3
Acc to Non-User	13.4	14.9	15.8	16.8	18.5	21.4	13.4	14.9	15.7	16.8	18.7	21.6	13.4	14.9	15.9	17.1	19.0	22.0
Subtotal:	32.5	36.2	38.5	41.3	45.8	53.6	32.5	36.2	38.5	41.2	45.2	52.4	32.5	36.2	38.8	42.7	47.6	55.5
Right-of-Way Associated																		
Partitioning	1.1	1.3	1.4	1.5	1.8	2.1	1.1	1.3	1.5	1.5	1.5	1.7	1.1	1.3	1.2	1.3	1.3	1.6
Displacement	2.2	2.5	2.6	2.8	3.1	3.6	2.2	2.5	2.6	2.8	3.1	3.5	2.2	2.5	2.3	2.5	2.7	3.2
Constr Incon	2.1	2.4	2.5	2.7	3.0	3.5	2.1	2.4	2.5	2.7	3.0	3.5	2.1	2.4	2.0	2.2	2.5	2.9
Proprty Values	1.8	2.0	2.1	2.3	2.6	3.0	1.8	2.0	2.2	2.3	2.6	3.0	1.8	2.0	1.9	2.0	2.2	2.6
Subtotal:	7.3	8.1	8.7	9.3	10.4	12.3	7.3	8.1	8.8	9.3	10.1	11.8	7.3	8.1	7.5	8.0	8.8	10.4
Economic																		
Employment	6.6	7.3	7.6	7.8	8.2	8.9	6.6	7.3	7.7	7.9	8.3	9.0	6.6	7.3	7.4	7.6	8.0	8.7
Personal Income	9.1	10.1	10.5	10.9	11.5	12.6	9.1	10.1	10.5	11.0	11.6	12.7	9.1	10.1	10.5	10.9	11.5	12.6
Indus Dist	1.5	1.7	1.8	1.8	1.9	2.1	1.5	1.7	1.8	1.8	1.9	2.1	1.5	1.7	1.8	1.8	1.9	2.1
Pop Dist	.4	.4	.4	.5	.5	.6	.4	.4	.5	.5	.6	.6	.4	.4	.5	.5	.6	.6
Subtotal:	17.6	19.5	20.3	21.0	22.1	24.2	17.6	19.5	20.5	21.2	22.4	24.4	17.6	19.5	20.2	20.8	22.0	24.0
Metropolitan Form and Design																		
Land Use Dist	.7	.8	.8	.9	1.0	1.1	.7	.8	1.2	1.4	1.7	1.9	.7	.8	1.0	1.0	1.1	1.3
Housing	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Metro Design	1.9	2.1	2.2	2.4	2.7	3.2	1.9	2.1	2.4	2.6	2.8	3.2	1.9	2.1	2.6	2.9	3.3	3.9
Subtotal:	2.6	2.9	3.1	3.3	3.7	4.3	2.6	2.9	3.6	4.0	4.5	5.1	2.6	2.9	3.6	3.9	4.4	5.2
Sociological-Political																		
Ind Life Style	7.0	7.8	8.1	8.5	9.1	10.2	7.0	7.8	8.6	9.4	10.4	11.4	7.0	7.8	9.4	10.3	11.5	12.8
Commty Involvmt	3.9	4.3	4.6	5.0	5.5	6.3	3.9	4.3	4.8	5.1	5.6	6.2	3.9	4.3	5.0	5.4	6.0	6.8
Government Form	1.6	1.8	1.9	2.0	2.3	2.7	1.6	1.8	2.0	2.2	2.5	2.7	1.6	1.8	1.9	2.0	2.3	2.7
Tax Policy	.9	1.0	1.1	1.2	1.3	1.5	.9	1.0	1.2	1.3	1.5	1.7	.9	1.0	1.6	1.8	2.1	2.3
Govt Services	3.2	3.6	3.9	4.2	4.6	5.5	3.2	3.6	4.0	4.4	4.8	5.5	3.2	3.6	4.5	4.8	5.5	6.2
Subtotal:	16.6	18.5	19.6	20.8	22.7	26.1	16.6	18.5	20.6	22.4	24.8	27.5	16.6	18.5	22.4	24.3	27.4	30.8
Scarce Resources																		
Radio Reception	2.2	2.5	2.6	2.8	3.1	3.6	2.2	2.5	2.6	2.8	3.1	3.6	2.2	2.5	2.6	2.8	3.1	3.6
Elec Power Cap	2.5	2.8	3.0	3.1	3.4	4.0	2.5	2.8	2.7	2.5	2.4	2.8	2.5	2.8	2.7	2.5	2.4	2.8
Ecology	1.8	2.0	2.1	3.3	3.6	4.2	1.8	2.0	3.1	4.4	6.1	8.4	1.8	2.0	3.1	4.4	6.1	8.4
Subtotal:	6.5	7.3	7.7	9.3	10.2	11.8	6.5	7.3	8.4	9.7	11.6	14.8	6.5	7.3	8.4	9.7	11.6	14.8
GRAND TOTAL:	83.2	92.4	97.9	105.0	115.0	132.2	83.2	92.4	100.4	107.8	118.6	136.0	83.2	92.4	100.9	109.4	121.8	140.7

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