Estimating Socioeconomic Impacts of Transportation Systems

Robert E. Taggart, Jr., and Nancy S. Walker, Ernst and Ernst, Washington, D.C.
Martin M. Stein, Maryland Department of Transportation, Baltimore

This study develops a methodology to estimate the socioeconomic impacts of multimodal transportation plans and programs in Maryland. The impacts include government expenditures of plan implementation, socioeconomic impacts of expenditures (i.e., personal income, employment, and population), displacement of businesses and households, and land use, accessibility, safety, and socioeconomic impacts of new transportation services and facilities (i.e., personal income, employment, and population). The programs evaluated include the Port of Baltimore; Baltimore-Washington International Airport; general aviation airports; rail (commuter and intercity) facilities; mass transit (bus and rail rapid transit); Interstate, primary, and secondary highway systems; low-capital improvements; and operating programs. The methodology consists of 26 impact-estimating equations, each of which was developed for statewide, regional, and county levels of detail. As a test application, the equations were used to evaluate the impacts of a 20-year $10-billion Maryland transportation plan. Socioeconomic impacts related to expenditures and new facilities or services were shown to generate $18 billion in personal income over this period with an average annual employment impact of 48 000 jobs and an average annual population impact of 100 000 people. The Baltimore region experienced the largest impact (83 percent of total statewide impacts). The Baltimore city and Baltimore County areas experienced 60 percent of the Baltimore region's impact.

The value of a transportation system is measured by the ultimate social and economic benefits, as well as the negative effects, the system contributes. Both citizens and public officials are demanding information concerning personal income, employment, economic growth, population, mobility, community disruption, and other potential impacts of proposed transportation systems before implementation decisions are made. These items are known as socioeconomic effects.

Recognition of the usefulness of socioeconomic impact analysis in evaluating transportation investments has increased dramatically. This impact information helps citizens and public officials to understand the implications of proposed and ongoing transportation system plans and programs. Socioeconomic information facilitates decisions concerning how a transportation system should be operated, maintained, and expanded to attain national, state, and local social and economic objectives. It also facilitates the integration of programs for transportation system change with those of other public and private organizations to preserve and promote desired social and economic conditions.

To date, socioeconomic impact analyses have focused on evaluating proposed transportation changes at the project and corridor levels. Although effective techniques have been developed for these levels, the demand for socioeconomic impact analyses in state transportation system planning has not been satisfied. The current state of the art fails to accommodate the requisite attributes of an effective state system-level socioeconomic impact assessment methodology in the following respects:

1. Most socioeconomic impact models have been developed for the regional or local levels of planning; few have been applied or are applicable to state planning processes.
2. Most models consider only the highway mode; none incorporate all modes of transportation.
3. Few models consider transportation programs other than capital improvement programs or provide the capability to integrate the effects of various programs.
4. Most models focus on determining the demand for transportation facilities and services, given exogenous inputs of population and economic activity distribution; few models determine the population and economic-activity impacts of transportation.
5. The models that do provide estimates of the effect of transportation (highway mode) on population and employment distribution fail to account for growth induced by transportation. Models that do account for this aspect are applicable only at the multistate regional level or are prohibitively expensive to use as an ongoing planning tool, or both.
6. Most techniques that assess the socioeconomic effects of transportation were developed for and are currently applicable to project planning only.
7. No universally acceptable framework for the integration of the complex of socioeconomic impacts and their application to the evaluation of proposed transportation programs is available.

The study discussed in this paper was designed to develop a methodology capable of providing estimates of the potential socioeconomic impacts of transportation system plans and programs at the state, multicounty-region, and county levels of detail.

The methodology resulting from this study was developed in three steps: (a) identification of essential characteristics of an effective methodology, (b) review of existing techniques for measuring socioeconomic impacts of transportation services and facilities, and (c) improvements in existing techniques. Finally, the methodology's capability was illustrated by applying it to estimate the socioeconomic impacts of a proposed Maryland transportation system plan alternative. The impacts analyzed included government expenditures involved in plan implementation, socioeconomic impacts of expenditures (i.e., personal income, employment, and population), land use impacts, displacement of businesses and households, accessibility impacts, safety impacts, and the socioeconomic impact of new transportation services and facilities (i.e., personal income, employment, and population). The programs evaluated included the Port of Baltimore; Baltimore-Washington International (BWI) Airport; general aviation airports; rail (commuter and intercity) facilities; mass transit (bus and rapid rail); Interstate, primary, and secondary highway systems; low-capital improvements; and operating programs.

STUDY RESULTS

This study may make a significant contribution to the transportation system planning process in Maryland as a result of the development of a socioeconomic impact analysis requirements matrix. The matrix, which is presented in Figure 1, identifies the components of an effective socioeconomic impact methodology by specifying which impacts should be considered in Maryland's system planning process.

The responses obtained from interviews conducted for

Figure 1. Impacts that the methodology can estimate qualitatively and quantitatively.

PROGRAMS TO BE EVALUATED	Govt. Responsibility for Implementing the Plan	Personal Income[b]	Employment[b]	Population[b]	Land Use Impact	Business Displacement	Household Displacement	Accessibility Impact	Safety Impact	Personal Income[c]	Employment[c]	Population[c]
Port of Baltimore MCP[a]	QN	QN	QN	QN	QN	QN	QN	QN	QL	QN	QN	QN
BWI Airport MCP	QN	QN	QN	QN	QN	QN	QN	QN	QL	QN	QN	QN
General Aviation MCP	QN	QN	QN	QN				QN	QL	QN	QN	QN
Rail MCP	QN	QN	QN	QN	QN	QN	QN	QL	QL	QN	QN	QN
Mass Transit MCP	QN	QN	QN	QN	QN	QN	QN	QN	QL	QL	QL	QL
Interstate and Primary Highway System MCP	QN	QN	QN	QN				QN	QN	QN	QN	QN
Secondary Highway System MCP	QN	QN	QN	QN				QN	QN	QN	QN	QN
Low-Capital-Improvement Program	QN	QN	QN	QN								
Operating Program	QN	QN	QN	QN								
All MDOT Programs	QN	QN	QN	QN								

Notes: QN = The methodology developed during this study provides for the quantitative estimation of this program impact.

QL - The methodology developed during this study provides for the qualitative estimation of this program impact.

Blank - This program impact is not amenable to either quantitative or qualitative estimation.

[a] MCP = Major Capital Program.

[b] Impact of expenditures to implement the programs.

[c] Impact of new transportation facilities and services.

this study represent a major contribution to the matrix. An interview instrument was developed and administered to 10 key public officials in Maryland. This interview instrument, or a modification of it, is useful in obtaining valuable information about the range and characteristics of opinions concerning the relative values of socioeconomic impacts. The determination of these relative values significantly improves trade-off analyses among state transportation plans and programs.

The socioeconomic impact methodology developed during this study is responsive to the components of the analysis requirements matrix. The extent to which the methodology provides for the estimation of relevant socioeconomic impacts is summarized in Figure 1. The symbols QN and QL that appear in this matrix identify whether the methodology provides quantitative or qualitative estimates of the impacts by program, respectively. Several cells in the matrix are blank to indicate program inpacts that are not amenable to either quantitative or qualitative estimation.

The methodology proposed for use in Maryland's transportation system planning process is comprised of a set of measurement techniques. Each technique is designed to estimate a specific impact for a specific transportation program or set of programs. An impact estimate represents the difference in a socioeconomic characteristic that would occur if a program were implemented versus if it were not implemented. The methodology is designed to generate annual impact estimates for the 1978-2000 planning period. Impact estimates are reported by program or sets of programs in the matrix format. This format was used because interviews conducted for this study indicate that impact estimates for a system plan or program are not amenable to objective aggregation, such as a benefit/cost ratio or other single index of worth. Consequently, a disaggregate presentation of impact estimates, such as the matrix, is the most understandable and useful format for reporting impact analyses.

The methodology is documented in two parts to facilitate its use by the Maryland Department of Transportation and other parties. First, the measurement techniques are summarized in equation form. These equations and the definitions of the variables and constants are reproduced in Figures 2 and 3. Second, the methodology is documented in a set of working papers. A working paper describes each technique's derivation. It also describes the assumptions and major limitations of the techniques and presents the sources of data used to estimate the variables and constants for applying it.

Application of the measurement techniques requires collection of data to estimate the variables and constants that appear in the equations and, subsequently, performance of the mathematical operations specified in the equation. Figure 4 presents the equation used to estimate the personal income impact of the Port of Baltimore as an illustration of how the measurement techniques are applied.

The methodology presented in this report is a significant improvement to the state of the art. Specifically, these improvements include the following:

1. Development of a measurement technique where none previously existed;
2. Development of a complete set of socioeconomic impacts relevant to Maryland Department of Transportation system planning;
3. Generation of data previously available to permit use of existing techniques or to improve the accuracy of their estimates;

Figure 2. Socioeconomic impact-estimating equations.

Impacts	Equations
Government Financial Responsibility	$G_{nh} = X_{nph} G_{ph}$ (1) $G_{sh} = X_{sph} G_{ph}$ (2) $G_{ch} = X_{cph} G_{ph}$ (3)
Personal-income Impact of Expenditures to Implement each Program	$Y_{psh} = k_i G_{psh} - k_i b_s T_{psh} + k'_i c_f G_{pfh}$ (4) $Y_{prh} = \frac{1}{1-(a_r b_r)} G_{prh} - b_r T_{prh} + A_{prh}$ (5) $Y_{pch} = Y_{prh} \frac{Y_{ch}}{Y_{rh}}$ (6)
Employment Impact of Expenditures to Implement each Program	$E_{psh} = \left(\frac{E_{sh}}{Y_{sh}}\right) Y_{psh}$ (7) $E_{prh} = \left(\frac{E_{sh}}{Y_{rh}}\right) Y_{prh} + A_{prh}$ (8) $E_{pch} = E_{prh} \left(\frac{E_{ch}}{E_{rh}}\right)$ (9)
Population Impact of Expenditures to Implement each Program	$P_{psh} = E_{psh} \left(\frac{P_{sh}}{E_{sh}}\right)$ (10) $P_{prh} = E_{prh} \left(\frac{P_{rh}}{E_{rh}}\right) + A_{prh}$ (11) $P_{pch} = P_{prh} \left(\frac{P_{ch}}{E_{rh}}\right)$ (12)
Land Use Impacts for the Port. BWI Rail and Mass Transit MCP's	$LU_{psh} = \sum_q L_{qh} - 1978$ (13) LU_{prh} = (same as LU_{psh} except $\sum_q$ refers to the projects in the region) (14) LU_{pch} = (same as LU_{psh} except $\sum_q$ refers to the projects in the county) (15)
Business Displacement Impact of the Port. BWI, Rail and Mass Transit MCP's	$RB_{psh} = \sum_q DB_{qh} - 1978$ (16) RB_{prh} = (same as RB_{psh} except $\sum_q$ refers to the projects in the county) (17) RB_{pch} = (same as RB_{psh} except $\sum_q$ refers to the projects in the county) (18)
Household Displacement Impact of the Port, BWI Rail and Mass Transit MCP's	$RH_{psh} = \sum_q DH_{qh} - 1978$ (19) RH_{phr} = (same as RH_{psh} except $\sum_q$ refers to the projects in the region) (20) RH_{pch} = (same as RH_{psh} except $\sum_q$ refers to the projects in the county) (21)
Accessibility Impact of the Port MCP	$AC_{2sh} = \left(\frac{D_{2sh} - D_{sh}}{D_{sh}}\right) P$ (22) AC_{2rh} = not amenable to estimation (23) AC_{2ch} = not amenable to estimation (24)

Figure 2. Continued.

Accessibility Impact of the BWI MCP	$AC_{2sh} = \sum_c \left[\left(\frac{TT_{xy'} - \left[TT_{xy}\left(\frac{DM_h - CP_b}{DM_h}\right) + TT_{xy'}\left(\frac{1-DM_h \; CP_b}{DM_h}\right)\right]}{\left[TT_{xy}\left(\frac{DM_h - CP_b}{DM_h}\right) + TT_{xy'}\left(\frac{1-DM_h - CP_b}{DM_h}\right)\right]} \right) \left(\frac{DM_{ch}}{\sum_c DM_{ch}}\right) \right]$ (25)
	AC_{3rh} = (same as AC_{3sh} except $\sum_c$ refers to the counties in each region) (26)
	$AC_{3ch} = TT_{xy'} \left[\frac{TT_{xy}\left(\frac{DM_h - CP_b}{DM_h}\right) + TT_{xy'}\left(\frac{1 - DM_h - CP_b}{DM_h}\right)}{TT_{xy}\left(\frac{DM_h - CP_b}{DM_h}\right) + TT_{xy'}\left(\frac{1 - DM_h - CP_b}{DM_h}\right)} \right]$ (27)
Accessibility Impact of the General Aviation MCP	$AC_{4sh} = \sum_c \left(\frac{TT_{xy'} - \sum_{xy} \left[(TT_{xy})(Q_{xy}) \left(\left[\frac{DM_{Bh} - CP_{Bb}}{DM_{Bh}} \right] \right) \right] + \left[TT_{xy'} \left(1 - \frac{DM_{y'h} - CP_{y'b}}{DM_{y'h}} \right) \right]}{\sum_{xy} \left(\left[(TT_{xy})(Q_{xy}) \left(\frac{DM_{y'h} - CP_{y'b}}{DM_{y'}} \right) \right] + \left[TT_{xy'} \left(1 - \frac{DM_{y'h} - CP_{y'b}}{DM_{y'h}} \right) \right] \right)} \right)$ (28)
	AC_{4rh} = (same as AC_{4sh} except $\sum_c$ refers to the counties in each region) (29)
	$AC_{4ch} = \frac{TT_{xy'} - \sum_{xy} \left[(TT_{xy})(Q_{xy}) \left(\frac{DM_{y'h} - CP_{y'b}}{DM_{y'h}} \right) \right] + \left[TT_{xy'} \left(1 - \frac{DM_{y'h} - CP_{y'b}}{DM_{y'h}} \right) \right]}{\sum_{xy} \left(\left[(TT_{xy})(Q_{xy}) \left(\frac{DM_{y'h} - CP_{y'}}{DM_{y'h}} \right) \right] + \left[TT_{xy'} \left(1 - \frac{DM_{y'h} - CP_{y'h}}{DM_{y'h}} \right) \right] \right)}$ (30)
Accessibility Impact of the Mass Transit MCP	$AC_{6rh} = \sum_c \frac{\sum_a \left[TT_{cah} \left(\frac{L_{cah}}{\sum_a L_{cah}} \right) \right] - \sum_a \left[TT_{cab} \left(\frac{L_{cab}}{\sum_a L_{cab}} \right) \right]}{\sum_a \left[TT_{cab} \left(\frac{L_{cab}}{\sum_a L_{cab}} \right) \right]}$ (31)
	$AC_{6ch} = \frac{\sum_a \left[TT_{cah} \left(\frac{L_{cah}}{\sum_a L_{cah}} \right) \right] - \sum_a \left[TT_{cab} \left(\frac{L_{cab}}{\sum_a L_{cab}} \right) \right]}{\sum_a \left[TT_{cab} \left(\frac{L_{cab}}{\sum_a L_{cab}} \right) \right]}$ (32)

Figure 2. Continued.

Accessibility Impact of the Interstate, and Primary and Secondary Highway System MCP's combined	$AC_{7sh} = \dfrac{\sum_c \left[TT_{xy} \left(\dfrac{P_y}{\sum_y P_y} \right) \right]_h}{\sum_c \left[TT_{xy} \left(\dfrac{P_y}{\sum_y P_y} \right) \right]_b}$	(33)
	AC_{7rh} = (same as AC_{7sh} except $\sum_c$ refers to sum of the counties in the region)	(34)
	$AC_{7ch} = \dfrac{\left| TT_{xy} \left(\dfrac{P_y}{\sum_y P_y} \right) \right|_h}{\left| TT_{xy} \left(\dfrac{P_y}{\sum_y P_y} \right) \right|_b}$	(35)
Safety Impact of the Interstate/Primary and Secondary Highway Systems MCP's combined	$I_{sph} = (IR_{sh} - IR_{sph})\, MVM_{sh}$	(36)
	$F_{sph} = (FR_{sh} - FR_{sph})\, MVM_{sh}$	(37)
Personal-Income Impact of the New Port Facilities and Services	$Y_{2sh} = k_i \left[\sum_e \left(d_e \left[DM_{eh} - \left(CP_{eh} - CP_{2eh} \right) \right] \right) \right] + k_i VP_{2sh} + A_{2sh}$	(38)
	$Y_{2rh} = \left(k_r \right) \left(Y'_{2rh} \right) + A_{2rh}$	(39)
	$Y_{2ch} = Y_{2rh} \left(\dfrac{Y_{ch}}{Y_{rh}} \right)$	(40)
Personal-Income Impact of New BWI Transportation Facilities and Services	$Y_{3sh} = k_s \left[\sum_e \left(d_e \left[DM_{eh} - \left(CP_{eh} - CP_{3eh} \right) \right] \right) \right] + k_s VP_{3sh} + A_{2sh}$	(41)
	$Y_{3rn} = \left(k_r \right) \left(Y'_{3rh} \right) + A_{3rh}$	(42)
	$Y_{3ch} = Y_{3rh} \left(\dfrac{Y_{ch}}{Y_{rh}} \right)$	(42)
Personal-Income Impact of New General Aviation Transportation Facilities and Services	$Y_{4sh} = \sum_c Y_{4ch}$	(43)
	$Y_{4rh} = \sum_c Y_{4ch}$ for all counties within the region	(44)
	$Y_{4ch} = k_c \left(\left[\dfrac{CP_{4ch}}{CP_{ch}} \right] \left[\sum_i \left(v_i \left[EY_{cih} - EY_{cib} \right] \right) \right] \right) + A_{4ch}$	(45)

Figure 2. Continued.

Personal-Income Impact of New Rail Facilities and Services	$Y_{5sh} = k_s\left(\sum_c \left[\left(\frac{Y_{ich}}{Y_{icb}}\right)\left(Y'_{i5cb}\right) + f_c TC_{5cb}\right]\right)$ (46)
	$Y_{5rh} = k_r\left(\sum_c \left[\left(\frac{Y_{ich}}{Y_{icb}}\right)\left(Y'_{i5cb}\right) + f_c TC_{5cb}\right]\right) + A_{5rh}$ (47)
	$Y_{5ch} = k_c\left[\left(\frac{Y_{ich}}{Y_{icb}}\right)\left(Y'_{i5cb}\right) + f_c TC_{5cb}\right] + A_{5ch}$ (48)
Personal-Income Impact of New Interstate Primary and Secondary Highway Systems Facilities and Services	$Y_{7sh} = S_{sh}\left[\left(M_t A_{h-h'} + M_{t'} A_{h-h''} + M_{t''} A_{h-h'''}\right)\left(H'_f\right)\right] +$ (49)
	$S_{sh}\left[\left(1+C_{h-5}\right)\left(M_{t'} A_{h-h''} H_f + M_{t''} A_{h-h'''}\right)\left(H_f\right)\right]$
	$Y_{7rh} = S_{rh}$ (same as Y_{7sh}) $+ A_{7rh}$ (50)
	$Y_{7ch} = S_{ch}$ (same as Y_{7sh}) $+ A_{7ch}$ (51)
Employment Impact of New Port Facilities and Services	$E_{2sh} = B_{si}\left[\sum_e \left(g_e\ DM_{eh} - \left(CP_{eh} - CP_{2eh}\right)\right)\right] + B_{si} EP_{2sh} + A_{2sh}$ (52)
	$E_{2rh} = Y_{2rh}\left(\frac{E_{rh}}{Y_{rh}}\right) + A_{2rh}$ (53)
	$E_{2ch} = E_{2rh}\left(\frac{E_{ch}}{E_{rh}}\right) + A_{2ch}$ (54)
Employment Impact of New BWI Facilities and Services	$E_{3sh} = B_{si}\left[\sum_e \left(g_e\left[DM_{eh} - \left(CP_{eh} - CP_{3eh}\right)\right]\right)\right] + B_s EP_{3sh} + A_{2sh}$ (55)
	$E_{3rh} = Y_{3rh}\left(\frac{E_{rh}}{Y_{rh}}\right) + A_{3rh}$ (56)
	$E_{3ch} = E_{3rh}\left(\frac{Y_{3ch}}{Y_{3rh}}\right)$ (57)
Employment Impact of New General Aviation Facilities and Services	$E_{4sh} = \sum_c E_{4ch}$ (58)
	$E_{4rh} = \sum_c E_{4ch}$ for all counties within the region (59)
	$E_{4ch} = Y_{4ch}\left(\frac{E_{ch}}{Y_{ch}}\right)$ (60)

Figure 2. Continued.

Employment Impact of New Rail Facilities and Services	$E_{5sh} =$ (61) $\left[Y_{5sh} - \sum_c \left(f'_c \; TC_{5cb}\right)\right] \left[\frac{E_{sh}}{Y_{sh}}\right] - \sum_c \left[\frac{\left(1-f'_c\right)\left(TC_{5cb}\right)}{w}\right]$ $E_{5rh} =$ (62) $\left[Y_{5rh} - \sum_c \left(f'_c \; TC_{5cb}\right)\right]\left[\frac{E_{rh}}{Y_{rh}}\right] - \sum_c \left[\frac{\left(1 - f'_c\right)\left(TC_{5cb}\right)}{w}\right] + A_{5rh}$ $E_{5ch} =$ (63) $\left[\left(Y_{5ch} - f'_c \; TC_{5ch}\right)\left(\frac{E_{ch}}{Y_{ch}}\right)\right] - \left[\frac{\left(1 - f'_c\right)\left(TC_{5cb}\right)}{w}\right]$
Employment Impact of new Interstate, Primary and Secondary Highway Systems, Facilities and Services	$E_{7sh} = S_{sh}\left[\left(M_t \; A_{h-h'} + M_{t'} \; A_{h-h''} + M_{t''} \; A_{h-h'''}\right)\left(H'_f\right)\right] +$ (64) $S_{sh}\left[\left(1+C_{h-5}\right)\left(M_{t'}A_{h-h''}H_f + M_{t''}A_{h-h'''}\right)\left(H_f\right)\right]$ $E_{7rh} = S_{rh}$ (same as E_{7sh}) $+ A_{7rh}$ (65) $E_{7ch} = S_{ch}$ (same as E_{7sh}) $+ A_{7ch}$ (66)
Population Impact of the new Port, BWI and Rail Facilities and Services	$P_{psh} = E_{psh} \quad \frac{P_{sh}}{E_{sh}}$ (67) $P_{prh} = E_{prh} \quad \frac{P_{rh}}{E_{rh}} + A_{prh}$ (68) $P_{pch} = E_{pch} \quad \frac{P_{ch}}{E_{ch}} + A_{pch}$ (69)
Population Impact of New General Aviation Facilities and Services	$P_{4sh} = \sum_c P_{4ch}$ (70) $P_{4rh} = \sum_c P_{4ch}$, for all counties in the region (71) $P_{4ch} = E_{4ch}\left(\frac{P_{ch}}{E_{ch}}\right)$ (72)
Population Impact of New Facilities and Services for Mass Transit	$P_{6ch} = \left(n_{ch} - \frac{PM_{ch}}{\sum_c PM_{ch}}\right)\left(\sum_c \left[\left(m_{ch} \; PM_{ch}\right) + A_{ch}\right]\right)$ (73)

Figure 2. Continued.

Population Impact of New Interstate, Primary and Secondary Highway Systems, Facilities and Services	$P_{7sh} = S_{sh}\left[\left(M_t A_{h-h'} + M_{t'} A_{h-h''} + M_{t''} A_{h-h'''}\right)\left(H'_f\right)\right] +$ (74) $S_{sh}\left[\left(1+C_{h-5}\right)\left(M_{t'}A_{h-h''}H_f + M_{t''}A_{h-H'''}\right) \quad H_f\right.$ $P_{7sh} = S_{rh}$ (same as P_{7sh}) $+ A_{7rh}$ (75) $P_{7ch} = S_{ch}$ (same as P_{7ch}) $+ A_{7ch}$ (76)

Figure 3. Variables for socioeconomic estimation equations.

A = Adjustment factor
B = Employment multiplier
C = An impact growth rate
CP = Capacity
CV = Percent of firms in the industry sector i for which access to aviation facilities are of "critical value"
D = Travel distance
DB = Business establishments displaced
DH = Households displaced
DM = Demand
E = Employment
EP = Employment of port dependent firms
EY = Industry earnings
F = Fatalities
FR = Fatalities rate
G = Government expenditures
H = An endogenous estimate of employment, personal income and population
I = Injuries
IR = Injury rate
L = Land in hectares (1 hectare = 2.47 acres)
LU = Land used in hectares
M = Kilometers of selected highway improvements (1 km = 0.6 mile)
MVM = Millions of vehicle kilometers traveled on the state highway system
P = Population
PM = The number of persons who will move into or within the county in a given time period
Q = Percent of over flow accommodated
RB = Business relocation impact
RH = Household relocation impact
S = Maryland's share of the BEA region impacts
T = Statewide revenue collections used to implement MDOT programs
TC = Transportation cost
TT = Travel time
VP = Value added of port dependent firms
X = Share of government expenditures
Y = Personal income
Y' = Direct personal income

a = Percent of consumer expenditures made locally
b = Marginal propensity to consume
c = Maryland share of BEA region's personal income
d = Direct expenditures per unit
f = The difference between the percent of county residents ownership of firms which would have experienced transportation cost increase and the per cent of increased transportation expenditures which would have accured to county transportation providers as personal income.
f' = Proportion of transportation costs which would have been absorbed by county residents
g = Direct employment impact rate
k = Income multiplier
k' = Indirect plus induced income multiplier
m = The percent of PM who will select a county in which to locate their residence on the basis of relative rail rapid transit service to employment by county.
n = An index of a counties' relative attractiveness as a residential location based on its rail rapid transit access to employment relative to other counties.

Figure 3. Continued.

p = Percent of metric tons passing through the Port of Baltimore usingPublic MPA facilities
t = Tax rate
v = Percent of Maryland firms for which air passenger and/or air freight service is of "critical value" in location choice.
w = annual average truckers wage

Subscripts:

b = Base year
c = County
e = Cargo type, i.e., freight or passenger
f = BEA region
h = Horizon year
h' = 1985
h'' = 1992
h''' = 1998
i = Industry sector
n = Federal government
p = MDOT program
q = MDOT project
r = Maryland region
s = State
t = 1978 - 1985
t' = 1986 - 1992
t'' = 1993 - 1998
x = Maryland county population centroid
y = A specified location
xy = Between x and y

2 = Port of Baltimore MCP
3 = Baltimore Washington International Airport MCP
4 = General Aviation MCP
5 = Rail MCP
6 = Mass Transit MCP
7 = Interstate and Primary Highway MCP
8 = Secondary Highway MCP
9 = Low Capital Program
10 = Operating Program

Figure 4. An example of how the measurement techniques are applied.

STEP 1: Identify the measurement technique to estimate the personal income impact of new Port of Baltimore services and facilities

$$Y_{2sh} = k_i \left[\sum_e \left(d_e \left[DM_{eh} - \left(CP_{eh} - CP_{2eh} \right) \right] \right) \right] + \left(k_i \right) \left(VP_{2sh} \right) + A_{2sh}$$

Note: • If $CP_{eh} > DM_{eh}$ enter 0 for the expression $\left[DM_{eh} - \left(CP_{eh} - CP_{2eh} \right) \right]$

• The result of $\left[DM_{eh} - \left(CP_{eh} - CP_{2eh} \right) \right]$ cannot exceed DM_{eh}

STEP 2: Define the variables, constants and subscripts

A_{2sh} = Adjustment factor.
CP_{eh} = Port of Baltimore public pier capacity by cargo type "e", in year "h".
CP_{2eh} = Port of Baltimore public pier capacity by cargo type "e", in year "h", added by the Port of Baltimore capital improvement program (program #2)

Figure 4. Continued.

DM_{eh} = Demand for use of Port of Baltimore public piers by cargo type "e", in year "h".

VP_{2sh} = Value added to the state economy in year "h" by industry dependent on the new Port of Baltimore public pier capacity.

Y_{2sh} = State personal income impact of the Port of Baltimore capital improvement program (program #2) in year "h" in dollars.

d_e = Direct expenditures in Maryland per metric ton resulting from cargo passing through the Port of Baltimore by cargo type "e" in dollars.

k_i = Income multiplier of type "i".

subscript e = 1, general cargo
= 2, container cargo
= 3, automobiles

subscript i = 1, type I mulitplier associated with industries experiencing direct expenditures resulting from cargo passing through the Port
= 2, type II multiplier associated with value added of Port dependent industries

STEP 3: Estimate the values of the variables and constants

A_{2sh} = 2% of Y_{2sh} before adjustment
CP_{1h} = 2,997,000 metric tons
CP_{2h} = 8,838,000 metric tons
CP_{3h} = 500,000 units
CP_{21h} = 0
CP_{22h} = 5,580,000 metric tons
CP_{23h} = 311,000 units

DM_{1h} = 2,871,000 metric tons
DM_{2h} = 7,384,000 metric tons
DM_{3h} = 315,000 units
VP_{2sh} = 158,000

d_1 = 41.27
d_2 = 26.90
d_3 = 77.04
k_1 = 1.48
k_2 = 2.97

STEP 4: Perform the indicated mathematical operations

$$Y_{2sh} = k_1 \left[\sum_{e=1}^{3} \left(d_e \left[DM_{eh} - \left(CP_{eh} - CP_{2eh} \right) \right] \right) \right] + \left(k_2 \right) \left(VP_{2sh} \right) + A_{2sh}$$

$$Y_{2sh} = 1.48 \left[\begin{array}{l} \$41.27 \ [2{,}871{,}000 - (2{,}997{,}000 - 0)] \\ + \ \$26.90 \ [7{,}389{,}000 - (8{,}838{,}000 - 5{,}580{,}000)] \\ + \ \$77.04 \ [315{,}000 - (500{,}000 - 311{,}000)] \end{array} \right] + (2.97)(\$158{,}000) + A_{2sh}$$

$$Y_{2sh} = 1.48\ [120{,}830{,}940] + 469{,}260 + A_{2sh}$$

$$Y_{2sh} = 179{,}299{,}050; \ \therefore \ A_{2sh} = (-.02)(179{,}299{,}050) - \$3{,}585{,}980$$

$$Y_{2sh} = 179{,}299{,}050 - 3{,}585{,}980 = 175{,}713{,}070$$

STEP 5: Record estimate

Y_{2sh} = $175,713,070

4. Modification of existing techniques to permit their application in Maryland and to the types of system improvements being considered in Maryland;
5. Adaptation of existing techniques that estimate current impacts to provide estimates of future impacts, net impacts, and impacts of changing the mix of capital or operating programs;
6. Clarification and improvement of assumptions underlying existing measurement techniques to ensure more accurate and comprehensible results;
7. Elaboration of an existing measurement technique to make it more comprehensive in its consideration of relevant variables and, consequently, more accurate in its results;
8. Modification of existing techniques to provide for impact estimation at the state, Maryland region, and county levels of detail; and

9. Capability of impact estimation at the single-project, multiple-project, and system levels of detail.

At the same time, the improvements made during this study do not resolve all methodological deficiencies in long-range socioeconomic impact analysis of transportation system plans or programs. Indeed, significant and perhaps insurmountable deficiencies remain. Major among these are the following:

1. Incomplete understanding of the cause-and-effect relationship between transportation system change and economic development,
2. Lack of techniques to accurately determine the combined impacts of a set of transportation programs,
3. Insufficient detail of impact estimates,
4. Lack of techniques to estimate system-level impacts of a set of individually minor projects that compositely may be of large significance,
5. Difficulties in determining the incidence of impacts,
6. Uncertainties associated with long-range projections of variables critical to impact estimation, and
7. Incomparable impact-estimating capabilities among types of system change.

These deficiencies mean that the results of using this methodology must not be regarded as accurate predictions of impacts. Nonetheless, the results can certainly be regarded as indicative of the general direction and order of magnitude of impacts that may be experienced. This type of information is inadequate to make unqualified decisions regarding optimal transportation system development. However, the results of this methodology do provide relevant information that should stimulate debate of state transportation plans and programs from the socioeconomic-impact perspective.

A case study performed with the methodology supports this conclusion. The methodology was used to estimate the socioeconomic impacts of a proposed Maryland statewide transportation system plan. This application generated the following types of socioeconomic impact information:

1. The cost of implementing the proposed plan will exceed $10 billion (1976 dollars). This cost will be shared by state, federal, and local governments. The respective shares of total cost will be 60, 39, and 1 percent. This funding arrangement differs from current arrangements in that the state will assume a significantly larger share of the costs to implement the highway capital improvement programs. The state's share for financing the primary highway program and the secondary highway program will increase from the current 30 percent to 86 and 66 percent, respectively.
2. To finance its share of plan implementation costs, the state will need to obtain $1.8 billion more than the current revenue structure will provide during the implementation period, 1978-1997. However, the $6 billion requirement represents a smaller portion of the gross state product than the Maryland department currently spends on transportation. Consequently, the tax burden to implement the plan will be less than the current level, despite the need for altering the existing funding structure to finance plan implementation.
3. The largest share of federal, state, and local plan expenditures will be used to carry out the operating program (30 percent of total expenditures). The mass transit and Interstate and primary highway programs will require similar funding levels for implementation (27 and 21 percent of total expenditures, respectively). At the other end of the spectrum are the Port of Baltimore (2.4 percent), BWI Airport (0.6 percent), general aviation (0.5 percent), and rail (0.9 percent) improvement programs. Together, the capital improvement programs will require 70 percent of total expenditures to implement.
4. Other costs of plan implementation include land taken from other productive uses such as agriculture. Land of recreational, scenic, or cultural value also may be taken to implement the plan. Business and household displacement will take place, and some community disruption may consequently occur. However, the methodology is not able to generate complete estimates of these potential impacts due to the lack of relevant data and inadequacies of available measurement techniques.
5. The total net personal-income impact of plan implementation is estimated to be almost $18 billion over the 1978-2000 period. This figure excludes the $10 billion that will be expended to implement the plan. The BWI Airport capital improvement program contributes over 50 percent of this cumulative impact. The mass transit, Port of Baltimore, and Interstate and primary highway programs are expected to account for 14.3, 12.4, and 9.2 percent of the total impact, respectively. It is significant to note that the Port of Baltimore impact estimate is based only on consideration of new public services and facilities. The impact would be substantially larger if private pier facilities were considered as well. For example, in 1974, public piers accounted for only 10 percent of cargo processed at all piers in the Port. Only public pier impacts were estimated because private investment in the Port is not part of the plan analyzed.
6. The impact trend over the analysis period basically exhibits steady growth in absolute terms and in terms relative to the state economy. In 1985, the net income effect of plan implementation is expected to be approximately $262 million. By the year 2000, it is estimated that this impact will reach $1864 million. The 1985 net income effect represents 0.5 percent of the projected gross state product in that year. This percentage is expected to increase steadily to 1.7 percent by the year 2000. Thus, the plan's personal-income impact is expected to grow more rapidly than gross state product and, consequently, will act as a steadily increasing stimulus to state economic activity.
7. The plan's impact on state employment and population also exhibits steady growth over time. In 1985, plan implementation may create the equivalent of 12 000 jobs that could support 26 000 people. By the year 2000, those figures may increase to 81 000 and 154 000, respectively. Thus, in 1985, the plan's impact may represent 0.5 percent of projected total state employment and 0.6 percent of total state population. In 2000, these percentages may climb to 3.2 and 2.8 percent, respectively.
8. Implementation of the plan may have a redistribution effect on the location of economic activity in the state. The Baltimore region is expected to receive a share of the plan's personal-income impact that is over twice as large as its current share of total state personal income. All other regions' shares of the estimated impact may be below their current shares of state personal income. Of these regions, the Washington region would fare the worst. All regions in the state, however, will experience net positive income, employment, and population impacts from plan implementation.
9. Personal-income impact distribution among counties within the Baltimore region is similar to the current distribution of total personal income in the region. Consequently, plan implementation is not expected to cause a redistribution of income among counties in the

region. Baltimore-region county impacts were estimated to illustrate the methodology's capability to generate county-level impact estimates. Impact estimates for counties outside of the Baltimore region were not made.

10. Plan implementation will result in accessibility improvements throughout the state. Travel time to port and commercial and general aviation services and facilities will decrease by 1, 75, and 15 percent, respectively, by the year 2000 with the implementation of these programs. Intrastate highway travel times may be reduced by 8 percent by the year 2000. Quantitative measures of state-level accessibility improvements resulting from the rail and mass transit programs could not be calculated. However, it is obvious that accessibility improvements of significance will occur as a result of implementation of the rail program. Without the program, rail freight service to some areas of the state would be discontinued. The personal-income impact of the program (an annual average of $10 million) attests to the potential significance of maintaining this accessibility. Significant accessibility improvements may be experienced as a result of the mass transit program as well. The program includes construction of a rail rapid transit system in the Baltimore region and completion of the 160-km (100-mile) Metrorail system. It also provides financial assistance to nonurbanized areas for the purchase of vehicles and equipment. This may provide transit dependents in these areas with new social and economic opportunities. Because a large percentage of the transit-disadvantaged reside in nonurbanized areas, the program may be of tremendous significance to persons residing in these areas of Maryland.

11. The primary safety impact of plan implementation will occur in the highway area. A conservative estimate is that 19 300 highway injuries and 270 highway deaths may be prevented with implementation of the plan.

SUGGESTIONS FOR FURTHER RESEARCH

As previously noted, several systems-level, socioeconomic-impact methodology deficiencies remain. The deficiencies described in this report provide several areas for potentially fruitful research. However, it is recommended that, before this type of research is conducted, the credibility and usefulness of the methodology in Maryland's transportation system planning process should be determined. Specifically, the researchers recommend that the following additional research be conducted.

First, determine the methodology's sensitivity to plans and programs. The methodology is designed to provide impact estimates of alternative plans and programs including alternative implementation-staging assumptions. However, this capability cannot be fully tested by evaluating a single plan. The transportation department could carry out this test by applying the methodology to estimate the socioeconomic impacts of the other two system plans it is considering for adoption. In addition, the detail of the impact estimate could be refined to permit the estimation of the incidence of the impacts for different socioeconomic or geographic areas.

Second, clarify the accuracy of the methodology's output. The methodology could be applied by using reasonable alternative assumptions concerning the values of constants and variables used in the case-study analysis. This could reveal the change of values the impact estimates could take and further test the accuracy of the results provided by the methodology. One of the alternative assumptions could be the use of historical expenditure patterns and analysis of their consequences to validate the accuracy of the equations used in this model.

Third, establish the credibility and usefulness of the methodology's output in state transportation planning and programming. This is the most important "next step" in establishing an effective system-level socioeconomic analysis capability. The case study suggests that the methodology output is responsive to the socioeconomic impact concerns of Maryland citizens, public officials, and planners in evaluating state transportation system plans and programs. Thus, it suggests that the methodology will be useful in deciding transportation system changes in Maryland. The extent to which the methodology and its output will actually be used for these purposes, however, is a major question. It will be answered only when the methodology is actually applied in planning and in public debate of alternative state transportation plans and programs. These steps will determine if additional basic research to develop improved measurement techniques is required, or if the present methodology is satisfactory for the state's purposes. They also would reveal the deficiencies in the methodology that, if resolved, would be most beneficial to socioeconomic impact analysis and evaluation of transportation system plans and programs.

ACKNOWLEDGMENT

This study was cosponsored by the Maryland Department of Transportation and the Federal Highway Administration, U.S. Department of Transportation.

Publication of this paper sponsored by Committee on Social, Economic, and Environmental Factors.

Residential Dislocation: Costs and Consequences

Jon E. Burkhardt, Ecosometrics, Inc., Bethesda, Maryland

This study investigated methods for predicting the dislocation consequences of alternative highway route and design proposals. It also assessed existing compensation practices in light of significant consequences. Data for these purposes were primarily derived from two household surveys before and after relocation. Interviews were conducted at six sites that represented a variety of project characteristics and geographic