REGIONAL IMPACTS OF NATIONAL TRANSPORT SYSTEMS ON POPULATION AND TRAVEL

By Martin M. Stein*

Transport investment needs are determined by increased demand for travel, resulting from growth in population and income and the constantly increasing mobility requirements of people and businesses. Completion of the Interstate highway system in the late 1970s may also affect travel patterns and travel volumes. Current research on the economic and demographic impacts of highways has indicated that the Interstate highway system will affect regional population and income growth. Other research studies, such as the recently completed Nationwide Personal Transportation Survey, imply that travel needs increase disproportionately with changes in income. By combining results of several research efforts with available forecasts of population and travel, valuable information can be derived on the changes in travel demand which may be expected. Some of these changes are the direct result of the impact of transport investment (structural changes) such as the Interstate highway system, while others are tied to a secular trend of increased income and economic activity. This paper attempts to identify the range of possible variation in travel demand which may be related to these structural changes and secular trends.

IMPACT OF INTERSTATE HIGHWAYS ON POPULATION

Table 1 shows six different forecasts of population growth by Census Division. The three standard forecasts were provided by the Bureau of Economic Analysis and the Bureau of the Census, both of the U.S. Department of Commerce. Census Series E figures are preliminary, but reflect a tendency toward revising earlier 1990 population estimates downward.¹ Thus the 33 per cent growth in U.S. population based on

*Manager, Socio-Economic Studies Group, Maryland Department of Transportation. The author completed this paper while employed by the Federal Highway Administration of the U.S. Department of Transportation. He gratefully acknowledges the statistical assistance of B. Goley and R. Stimpert. The models described were employed by the author and consultants to the agency in developing special background studies for the 1972 and 1974 Highway Needs Studies, and were prepared for submission to the U.S. Congress.

¹Census series forecasts are based on several different fertility assumptions (average number of births per woman). The three estimates used are Census Series E, “Preliminary Projection of the Population of States, 1975 to 1990;” Highway Needs (or extension of 1985 Census Series D estimates with subsequent revisions by States), “1972 National Highway Needs Report;” and Bureau of Economic Analysis estimates (equivalent to Census Series C), “State Projection of Income, Employment, and Population”. All three series have lower population forecasts than Census Series B, which was chiefly used by the local transport planners. This paper focuses on the comparison of population and travel estimates derived from different sources and an evaluation of the potential meaning of these variations for policy planners. It is assumed that the reader is familiar with assumptions utilised in standard demographic forecasts such as those published by the U.S. Census Bureau. The use of economic techniques naturally relies on other assumptions for developing estimates of employment and population changes.
### Table 1

**Forecasts of 1970 to 1990 Population Change by Census Division (percentages)**

<table>
<thead>
<tr>
<th>Census Division</th>
<th>Standard Forecasts</th>
<th>Forecasts Based on Completed Interstate Highway System</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bureau of Economic Analysis¹</td>
<td>Modified Census D Series²</td>
</tr>
<tr>
<td>New England</td>
<td>36</td>
<td>20</td>
</tr>
<tr>
<td>Middle Atlantic</td>
<td>29</td>
<td>20</td>
</tr>
<tr>
<td>East North Central</td>
<td>33</td>
<td>20</td>
</tr>
<tr>
<td>West North Central</td>
<td>24</td>
<td>13</td>
</tr>
<tr>
<td>South Atlantic</td>
<td>35</td>
<td>30</td>
</tr>
<tr>
<td>East South Central</td>
<td>25</td>
<td>22</td>
</tr>
<tr>
<td>West South Central</td>
<td>29</td>
<td>26</td>
</tr>
<tr>
<td>Mountain</td>
<td>34</td>
<td>37</td>
</tr>
<tr>
<td>Pacific</td>
<td>44</td>
<td>38</td>
</tr>
<tr>
<td>Total U.S.</td>
<td>33</td>
<td>25</td>
</tr>
</tbody>
</table>

*Population for 1970 was held constant, using revised data rather than the data for 1970 appearing in each of the publications.

¹Based on 1990 projections from Census I-C Series. Projections based on basic service employment growth trends by the Regional Economics Division of the Bureau of Economic Analysis, U.S. Department of Commerce.


³Census E Series, most recently adopted by Census Bureau.

⁴Extrapolation of estimates derived from simplified multiregional input-output tables (see text).

⁵Estimates based on accessibility and development potential weights (see text).

⁶Estimates produced by regional forecasting equations (see text).

The I-C Series may be compared with the 23 per cent increase in the recently adopted Series E forecasts. These three standard forecasts are compared with three different estimates derived from models which consider the impact of the Interstate highway network.²

The Creighton-Hamburg Accessibility model estimated the impact of the Interstate on 1970 and 1990 population estimates by weighting population in each region, using the rough estimates of the expected shift in population derived from accessibility and subsequent developmental potential. Development potential (or weight) is defined as:

\[
R_f = \frac{R_dJ}{\sum J|R_f - I}
\]

²A description of these models can be found in [1], [2] and [3].
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where

\[ R_f = \text{the expected development at a site} \]
\[ R_e = \text{the total development in the region (measured in floor space)} \]
\[ R_a = \text{the land area of the site} \]
\[ I = \text{the access integral of the site} \]
\[ J = \text{the total access integral of the regions.} \]

Weights for conditions in 1970 without Interstate highways and for 1990 with the completed Interstate mileage are used to measure differences from 1970 actual and estimated 1990 forecasts. This estimating technique was based on empirically observed development occurring after expressway construction, and thus required little data collection. Because the model measures expected development potential which often may not result, its use for forecasting purposes may be questioned.

The Faucett analysis utilized a simplified revision of the multi-regional input-output model, referred to as the "Constant Regional Imports Model". The model contained nine industry sectors for nine regions, and total shipments between regions for each sector were described, using the following relationship:

\[ S_y = T_y C_j \] (2)

where

\[ S_y = \text{total shipments from region } i \text{ to region } j \]
\[ T_y = \text{trade coefficient} \]
\[ C_j = \text{total consumption in region } j. \]

Although the simplified model was used to measure the impact of Interstate construction expenditures treated as exogenous additions to intersectoral transactions, a more complex revision of the model was tested and discarded. The "Gravity Parameter Model" permitted interregional shipments to vary after exogenous changes in expenditures by utilizing the following relationship:

\[ S_y = \frac{T_y S_i C_j}{S} \] (3)

where

\[ S = \text{total production in all regions} \]
\[ S_i = \text{sales in region } i. \]

The model developed impact estimates for Interstate expenditures from 1957 to 1971 of approximately $70 billion, and measured average annual employment generated by these expenditures. These employment estimates were extrapolated to indicate the average annual percentage change in employment to 1990 generated by the Interstate highway system. Then employment estimates were converted into population estimates by using 1970 Census employment-population ratios.4 While

\[ \text{For a complete description of this model see [4].} \]
\[ \text{4Input-output estimates were derived by the following steps: Introduce Federal Interstate expenditures in final demand and generate output, apply "value-added to output ratios" by sector by region to generate total value added by region, multiply estimates of marginal propensity to consume by value-added to obtain the next estimate of increase in final demand, distribute estimate of increase in final demand to sectors based on pattern of regional consumption expenditures in 1963, insert consumption expenditures by sector into final demand and calculate the next estimate of increase in output, and repeat steps two through five until there is no significant change in value-added.} \]
the gravity revision was not utilised for estimating purposes because of a lack of data, this simplified approach yielded results which could not be considered reliable. However, when these impact estimates were converted into forecast estimates, it was possible to examine the findings for reasonableness by comparing them with expected or forecast changes in population.  

The Curtis Harris model is an operating interregional dynamic model which forecasts industrial activity and other variables at the regional level. The model is subdivided into 99 industry, 69 equipment, 28 construction and 8 government sectors, with data developed for 1966 and 1967 for 173 functional economic areas (multicounty areas defined by the Bureau of Economic Analysis of the U.S. Department of Commerce). Forecasts are derived from recursive iteration of the linear equations describing each sector, with regional adjustments so that national control totals are not exceeded. The national output totals by industry are based on 1985 I-O forecasts of Clopper Almon at the University of Maryland, and include adjustments for changes in technology. Transport investment is considered as a basic element in determining industrial output through the use of “shadow prices” or marginal transport costs. These costs are defined as:

$$TQ^i_j = \frac{TI^i_j}{T} = f(S^i_k, D^i_k, T^i_k)$$  

where

- $TQ^i_j$ = transport cost of shipping a marginal unit of output from industry $i$ out of region $j$ in year $t$.
- $TI^i_j$ = transport cost of obtaining a marginal unit of input from industry $i$ into region $j$ in year $t$.
- $S^i_k$ = total supply of goods classified by industry $i$ in year $t$ for each region.
- $D^i_k$ = total demand for goods classified by industry $i$ in year $t$ for each region.
- $T^i_k$ = transport cost of shipping a unit of commodity $i$ from region $k$ to region $j$ in year $t$.

with the following notation:

- $i$ = industry sectors
- $h, j, k$ = region or regions (1, … 173)
- $t$ = year.

The marginal costs are computed by a linear programming algorithm which considers cost, speed and distance relationships between regional nodal points and adjusts regional shares of output accordingly. Since the results of the model are forecasts of employment, income and population, they may be contrasted with standard forecasts which do not attempt to consider changes in transport investment, infrastructure or accessibility. Furthermore, since the model is recursive, tests of accuracy can be made by comparing base year (1966) results with actual 1970 data.

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3Estimates for 1990 were derived from extrapolations of an impact analysis of the effects of the Interstate highway system from 1957 to 1977. Average annual employment generated by census division was used to project the 1970 census employment to 1990. This employment projection was divided by 1970 employment population participation rates. See [5] and Census of Population, PC(1) C1, Table 161.
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Some conceptual limitations which the use of this model has helped to overcome are that the model (1) defines regions in terms of functional economic areas which include surrounding non-urban portions of regional economic base; (2) integrates transport cost as a factor in industrial location; and (3) formulates forecasts based on impact of hypothetical investment alternatives.

COMPARISON OF POPULATION FORECASTS

A simple comparison of results derived from these forecasts is shown in Table 1. Both standard and transport forecasts are substantially different. However, regional differences for census forecasts seem to shift in the same direction, while transport-related forecasts have multidirectional shifts in both relative and absolute terms. The extent of variation is significant, and it is thus evident that estimates of transport changes may affect forecasts through changes in accessibility or in the industrial base. Since census forecasts are based on fertility assumptions and migration trends which do not consider changes in infrastructure, results of alternative models can be useful to identify potential impacts, particularly at the regional or even small unit level, which could change the direction of historical trends or accelerate existing trends.

Each forecast results in estimates which when evaluated provide useful guidance and background information of possible help in formulating transport policy (e.g., consideration of the population distribution effects of Interstate highways). There are also by-products from the implementation of economic models such as the multi-regional input-output model which serve to justify their utilisation, especially if certain policy questions are formulated. For example, input-output analysis may be used to measure the impact of construction expenditures in regions with high rates of unemployment.6

Also, the accessibility weighting techniques may prove helpful in disaggregating regional impacts of national networks into changes in the structure of activity for metropolitan areas or even small geographical units. Finally, the forecasting or econometric approach contains potential for simulation which enables us to consider all the hypothetical changes in transport networks.7 Results of these comparisons will help us to consider environmental and resource constraints8 and the impact of changes in cost of gasoline and size of automobiles.

POPULATION AND TRAVEL FORECASTS: POSSIBLE SOURCES OF ERROR

The “1972 National Highway Needs Report” population forecast to 1990 was based on an extension of the 1985 Census Series D estimates, with subsequent revisions by States. As shown in Table 2, population in 1990 is expected to vary from 250 million to 269 million. The estimate used in the Highway Needs report differs from the recent estimate prepared by the Census Bureau by approximately 3 million. Even

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6For further illustrations see [6].
7For the results of evaluating several networks see [7].
8A brief illustration of the use of impact estimates as anticipatory indicators is described in [8].
TABLE 2

Forecasts of Population and Vehicle Miles of Travel, 1990

<table>
<thead>
<tr>
<th>Census Division</th>
<th>Standard Estimates</th>
<th>Transportation Impact Forecasts</th>
<th>Vehicle-miles of travel Estimates (millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bureau of Economic Analysis¹</td>
<td>Highway Needs²</td>
<td>Census E Series³</td>
</tr>
<tr>
<td>New England</td>
<td>16,138</td>
<td>14,171</td>
<td>14,682</td>
</tr>
<tr>
<td>Middle Atlantic</td>
<td>48,146</td>
<td>44,607</td>
<td>43,470</td>
</tr>
<tr>
<td>West North Central</td>
<td>20,269</td>
<td>18,446</td>
<td>18,555</td>
</tr>
<tr>
<td>South Atlantic</td>
<td>41,442</td>
<td>39,927</td>
<td>38,818</td>
</tr>
<tr>
<td>East South Central</td>
<td>15,995</td>
<td>15,586</td>
<td>14,100</td>
</tr>
<tr>
<td>West South Central</td>
<td>24,938</td>
<td>24,338</td>
<td>23,867</td>
</tr>
<tr>
<td>Mountain</td>
<td>11,074</td>
<td>11,360</td>
<td>10,894</td>
</tr>
<tr>
<td>Pacific</td>
<td>38,113</td>
<td>36,692</td>
<td>37,058</td>
</tr>
<tr>
<td>United States</td>
<td>269,759</td>
<td>253,412</td>
<td>250,630</td>
</tr>
</tbody>
</table>

¹Based on 1990 projections from Census I-C Series. Projections based on basic service employment growth trends by the Regional Economics Division of the Bureau of Economic Analysis.
³Census E Series, most recently adopted by Census Bureau.
⁴Extrapolation of estimates derived from simplified multiregional input-output tables (see text).
⁵Estimates based on accessibility and development potential weights (see text).
⁶Estimates produced by regional forecasting equations (see text).
Table 3
Forecasts of Vehicle-Miles of Travel Based on Population

<table>
<thead>
<tr>
<th>Census Division</th>
<th>Estimated Vehicle-Miles of Travel¹ (Million)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Standard Population Estimates</td>
</tr>
<tr>
<td></td>
<td>Bureau of Economic Analysis</td>
</tr>
<tr>
<td>Middle Atlantic</td>
<td>355,878</td>
</tr>
<tr>
<td>East North Central</td>
<td>396,517</td>
</tr>
<tr>
<td>West North Central</td>
<td>149,821</td>
</tr>
<tr>
<td>South Atlantic</td>
<td>306,324</td>
</tr>
<tr>
<td>East South Central</td>
<td>118,229</td>
</tr>
<tr>
<td>West South Central</td>
<td>184,333</td>
</tr>
<tr>
<td>Mountain</td>
<td>81,855</td>
</tr>
<tr>
<td>Pacific</td>
<td>281,718</td>
</tr>
<tr>
<td>United States</td>
<td>1,993,961</td>
</tr>
</tbody>
</table>

¹Conversion of population and vehicle miles of travel was made with the following equation: (trip length) × (trips/person/year) × (population estimate) = vehicle miles of travel. Data sources for vehicle miles of travel per person obtained from the Nationwide Personal Transportation Survey Report [12]. Regional differences in trip length and trip frequency not considered.

²Travel estimates derived from population as described in footnote 1, and not corresponding to vehicle miles of travel estimates published in the 1972 Highway Needs Report shown in Table 2.
though the rates of change show greater variation than absolute totals, differences between regions may be substantial (compare Table 1). Also, variations in population are expected to be in age groups not likely to have a great effect on use of transport facilities by 1990 (e.g., a high forecast may mean that a higher fertility rate was used, resulting in more infants than adults of driver age). Another demographic factor is mentioned by Houthakker and Verleger [9], who note that areas of low population density have higher per capita consumption of gasoline. Higher consumption of gasoline and more travel is likely in regions with low densities; thus interregional population shifts may become an important factor in the relationship between population and travel estimates.

It is interesting to compare the results of several different population forecasts after they have been converted to changes in vehicle miles of travel. Differences in vehicle miles of travel indicate the maximum likely range of variation from existing estimates of travel which might be accounted for by different demographic forecasts or changes in regional growth, possibly stimulated by the completion of the Interstate highway system. For example, in the Mountain division population estimates could vary from 10,894,000 to 12,398,000, generating differences in estimates of travel that range from 3,444 million vehicle-miles to 11,354 million vehicle-miles. This variation represents a small share of the national error; but if this increase in travel volume occurs in one region or one state the corresponding impact on travel needs could be significant. Since annual total highway costs of accommodating 1,000 vehicle-miles of travel range from $1.50 for two-lane roads to $8.00 for 8-lane roads, variations in annual travel of these proportions could become important in estimating future transport investment needs.

INCOME AND TRAVEL FORECASTS: POSSIBLE SOURCES OF ERROR

If demographic forecasts are substantially accurate at the national level and somewhat less accurate at the regional level, variations in the forecasts may be responsible for regional shifts in transport investment requirements rather than changes in total national needs. However, if income changes produce substantially more travel per person, regardless of absolute population size, travel volumes will increase relatively and absolutely in each region. Although existing forecasts of vehicle-miles of travel may have considered this expected growth in income, it is possible to recompute the impact of increased income on travel by two different estimating procedures. Comparing results from these separate analyses may help to determine the possible

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9 The elasticity of demand is defined as the ratio of the percentage change in the quantity demanded to the percentage change in price that is responsible for the change in quantity demanded when "other things" are given and when the change in price approaches zero [10, p. 19]. The income elasticity of demand is the relative responsiveness of quantity demanded to changes in income [11].

10 It may be worth noting here that variations between census forecasts developed for earlier periods differed for each census region. For example, when census series 4 estimates for 1970 (see Current Population Report "Population Estimates", August 9, 1957, Series P-25, No. 160) are compared with actual 1970 results, variations of -14 to +9 are observed. Similar comparisons between Harris and Bureau of Economic Analysis estimates for 1990 yield differences of -3 to +14.
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extent or range of error. For example, one method used in developing data for Table 4 consists of applying existing relationships between income and travel to projected 1990 income. Data from the Nationwide Personal Transportation Survey [12] was used to develop an estimating equation for vehicle-miles of travel and household income, which was then applied to income projections prepared by the Bureau of Economic Analysis. An alternative approach to measuring the effect of rising income on travel utilizes the income elasticity relationships defined by Houthakker and Verleger [9] and data on gasoline consumption from Highway Statistics (see Table 5). It may be useful to compare results for changes in travel related to income derived from these two approaches. For example, elasticity relationships (which show the trade-offs individuals are willing to make between costs of travel and changes in their income) are based on statistically computed observations of aggregate experiences as reflected in changes in gasoline consumption and changes in income. On the other hand, the survey approach provides information on travel patterns or behaviour of households of differing income groups. Since the elasticity relationships are given for both long and short range conditions, the range of variation is somewhat greater.

**Table 4**

**Estimated Increase in Travel Related to Income: Survey Approach**

<table>
<thead>
<tr>
<th>Census Division</th>
<th>1990 Estimated Personal Income</th>
<th>Vehicle-miles of travel&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Vehicle-miles of travel&lt;sup&gt;2&lt;/sup&gt;</th>
<th>Total estimated vehicle-miles of travel&lt;sup&gt;3&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Per capita per year&lt;sup&gt;4&lt;/sup&gt;</td>
<td>Per household per year&lt;sup&gt;4&lt;/sup&gt;</td>
<td>household</td>
<td>person&lt;sup&gt;4&lt;/sup&gt;</td>
</tr>
<tr>
<td>New England</td>
<td>6,467</td>
<td>20,112</td>
<td>27,520</td>
<td>8,849</td>
</tr>
<tr>
<td>Middle Atlantic</td>
<td>6,801</td>
<td>21,151</td>
<td>28,804</td>
<td>9,262</td>
</tr>
<tr>
<td>East North Central</td>
<td>6,467</td>
<td>20,112</td>
<td>27,520</td>
<td>8,849</td>
</tr>
<tr>
<td>West North Central</td>
<td>5,929</td>
<td>18,439</td>
<td>25,454</td>
<td>8,185</td>
</tr>
<tr>
<td>South Atlantic</td>
<td>5,646</td>
<td>17,559</td>
<td>24,366</td>
<td>7,835</td>
</tr>
<tr>
<td>East South Central</td>
<td>4,976</td>
<td>15,475</td>
<td>21,792</td>
<td>7,007</td>
</tr>
<tr>
<td>West South Central</td>
<td>5,373</td>
<td>16,710</td>
<td>23,318</td>
<td>7,498</td>
</tr>
<tr>
<td>Mountain</td>
<td>5,505</td>
<td>17,121</td>
<td>23,825</td>
<td>7,661</td>
</tr>
<tr>
<td>Pacific</td>
<td>6,726</td>
<td>20,918</td>
<td>28,516</td>
<td>9,169</td>
</tr>
<tr>
<td>United States</td>
<td>6,166</td>
<td>19,176</td>
<td>26,364</td>
<td>8,477</td>
</tr>
</tbody>
</table>

<sup>1</sup>Total personal income divided by total population of each region. Source: *Survey of Current Business*, Department of Commerce, April 1972, Vol. 52, No. 4, Tables 3 and 4, pages 33 and 34.  
<sup>3</sup>Derived from regression equation \( Y_t = 2674·2 + 1·24X_t \) developed from data in [12], page 6, Table 2.  
<sup>5</sup>Vehicle-miles travelled per person multiplied by estimated 1990 population. Source: *Survey of Current Business*, Department of Commerce, April 1972, Vol. 52, No. 4, Table 4, page 34. Division totals adjusted to national total.

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### Table 5

**Estimated Increase in Travel Related to Real Income: Elasticity Estimates**

<table>
<thead>
<tr>
<th>Census Division</th>
<th>Income Elasticity</th>
<th>Estimated % change in personal real income 1969–1990</th>
<th>1970 motor fuel consumption thousands of gallons</th>
<th>Estimated 1990 gasoline consumption (thousands)</th>
<th>Estimate based on short range income elasticity</th>
<th>Estimate based on long range income elasticity</th>
<th>Estimated V.M.T. related to income increase (millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Short range</td>
<td>Long range</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New England</td>
<td>0.64</td>
<td>1.02</td>
<td>140.1</td>
<td>4,851,359</td>
<td>9,201,282</td>
<td>11,784,048</td>
<td>114,556</td>
</tr>
<tr>
<td>Middle Atlantic</td>
<td>0.60</td>
<td>0.97</td>
<td>128.2</td>
<td>13,020,826</td>
<td>23,036,445</td>
<td>29,212,744</td>
<td>292,332</td>
</tr>
<tr>
<td>East North Central</td>
<td>0.44</td>
<td>0.89</td>
<td>138.9</td>
<td>17,860,126</td>
<td>28,775,521</td>
<td>39,938,992</td>
<td>357,104</td>
</tr>
<tr>
<td>West North Central</td>
<td>0.48</td>
<td>0.68</td>
<td>129.3</td>
<td>8,339,987</td>
<td>13,516,117</td>
<td>15,672,837</td>
<td>158,679</td>
</tr>
<tr>
<td>South Atlantic</td>
<td>0.18</td>
<td>0.46</td>
<td>152.0</td>
<td>14,824,100</td>
<td>18,879,974</td>
<td>25,189,111</td>
<td>202,771</td>
</tr>
<tr>
<td>East South Central</td>
<td>0.47</td>
<td>0.80</td>
<td>147.3</td>
<td>6,274,838</td>
<td>10,618,971</td>
<td>13,669,107</td>
<td>116,295</td>
</tr>
<tr>
<td>West South Central</td>
<td>0.38</td>
<td>0.74</td>
<td>142.4</td>
<td>10,436,262</td>
<td>16,063,532</td>
<td>21,433,577</td>
<td>175,954</td>
</tr>
<tr>
<td>Mountain</td>
<td>0.70</td>
<td>0.94</td>
<td>148.9</td>
<td>4,721,800</td>
<td>9,643,321</td>
<td>11,330,715</td>
<td>112,441</td>
</tr>
<tr>
<td>Pacific</td>
<td>0.38</td>
<td>0.47</td>
<td>165.9</td>
<td>12,508,786</td>
<td>20,394,525</td>
<td>22,262,262</td>
<td>254,320</td>
</tr>
<tr>
<td>United States</td>
<td>0.44</td>
<td>0.77</td>
<td>141.2</td>
<td>92,956,735</td>
<td>150,708,895</td>
<td>194,023,016</td>
<td>1,817,549</td>
</tr>
</tbody>
</table>

1. Source: [9], Table 2, p. 13. Long and short range estimates defined by authors are based on historical data for the 48 contiguous States.
4. Equation: \([E_i] (\Delta I) (Q_o) + Q_o = Q_n\) where \(E\) = elasticity factor, \(\Delta I\) = percentage change in income, \(Q_o\) = old consumption. \(Q_n\) = new consumption, \(I\) = income.
5. \((Q_o) (M_1) = \) Estimated V.M.T. where \(Q_n\) = new consumption and \(M_1\) = ratio of V.M.T. to fuel consumption, 1970.
### Table 6
Summary of Variations in Estimated Travel

<table>
<thead>
<tr>
<th>Census Division</th>
<th>1990(^1) Estimated vehicle miles of travel (base index)</th>
<th>Possible Variations Resulting From: (^2)</th>
<th>Population Changes(^3)</th>
<th>Income changes: elasticity approach</th>
<th>Income changes: survey approach</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Standard forecasts</td>
<td>Impact forecasts</td>
<td>high</td>
<td>low</td>
</tr>
<tr>
<td>New England</td>
<td>100</td>
<td>126</td>
<td>111</td>
<td>116</td>
<td>108</td>
</tr>
<tr>
<td>Middle Atlantic</td>
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<td>148</td>
<td>134</td>
<td>158</td>
<td>139</td>
</tr>
<tr>
<td>East North Central</td>
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<td>102</td>
<td>113</td>
<td>101</td>
</tr>
<tr>
<td>West North Central</td>
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<td>102</td>
<td>92</td>
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</tr>
<tr>
<td>South Atlantic</td>
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<td>100</td>
<td>94</td>
<td>97</td>
<td>91</td>
</tr>
<tr>
<td>East South Central</td>
<td>100</td>
<td>100</td>
<td>88</td>
<td>111</td>
<td>87</td>
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<td>107</td>
<td>99</td>
<td>107</td>
<td>102</td>
</tr>
</tbody>
</table>


\(^2\)All these variations are explained in terms of indexes, the base being the estimated 1990 total vehicle-miles travelled by region given by the Highway Needs Report.

\(^3\)Resulting from taking the high and low of each group of forecasts. Refer to sources given in footnotes to Table 1. Differences in national population totals for 1990 are not adjusted to emphasise the range of variation.

\(^4\)Estimated vehicle-miles of travel as shown in col. 5 of Table 4 and its footnotes.

\(^5\)Estimated vehicle-miles of travel. Refer to Table 5, last two columns.
SUMMARY AND CONCLUSION

Table 6 presents a summary of results obtained by using changes in population, income and price to revise travel estimates. These revised estimates are compared with 1990 estimates presented in the Highway Needs Study (which for purposes of simplicity were used as the base for the index). Variations from the base represent the percentage of variation in 1990 travel attributable to factors such as growing population and growing income. For example, the Middle Atlantic Division (New York, New Jersey, and Pennsylvania) may have substantial population growth (especially if higher population forecasts are used) and growth in income which could result in significantly higher travel volumes. On the other hand, the West South Central division (Arkansas, Louisiana, Oklahoma and Texas) is not expected to have much greater growth in travel, and possibly will experience less than anticipated growth in travel, if income forecasts are accurate. Further analysis of the relationships between estimates of changes in travel, population and income will help to identify predictive equations which might be useful in refining existing travel estimates.\footnote{Preliminary regression analysis of the relationship between the growth in vehicle-miles of travel and population from 1970 to 1990 resulted in correlation coefficients of 0.69 if the Need Study Population estimate was used, and 0.60 by the C. Harris estimate. Other population estimates resulted in coefficients of 0.69 (Bureau of Economic Analysis) and 0.49 (Census Series "e"). If income growth was substituted (Survey of Current Business), the corresponding correlation coefficient was 0.59. Using change in civilian labour force (extrapolation of 1985 National Planning Association forecasts) resulted in a coefficient of 0.62.}

Planners may use these preliminary estimates of the potential range in future travel demand to predict the impact of these structural changes and secular trends on transport needs and investments. Finally, current research efforts are attempting to balance the effects of national and regional growth with possible decreases in travel resulting from energy shortages \footnote{For related discussions see [14]; [15, Figure N-11, p. N-32]; [16], [17]; [18]. Preliminary analysis indicates that the impact of increases in the price of gasoline relative to income changes may result in shifts to vehicles which are more gasoline-efficient rather than to sharp reductions in the demand for travel.}.

REFERENCES

REGIONAL IMPACTS OF NATIONAL TRANSPORT SYSTEMS

Martin M. Stein


