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THE VOLPE CENTER'S INTER-REGIONAL AUTO TRIP MODEL

A Review of Methodology, Assumptions, and Application

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BACKGROUND INFORMATION

The Volpe Center first estimated an inter-regional auto trip model as part of its effort to assess the market feasibility of maglev for the National Maglev Initiative (NMI).[1] The original intent was to develop a direct demand model for estimating inter-regional auto trips which could be used with a set of diversion models that were being developed by Charles River Associates.

To apply the diversion models (and estimate travel demand for a new mode), base year and future year estimates of person trips, by mode, are necessary. Base year estimates of person trips are readily available for two of the three major modes of inter-city travel. Air trips are available from the U.S. DOT's (RSPA) 10% ticket sample; and rail trips can be obtained from AMTRAK. However, since no nationwide data base exists that can provide estimates of auto trips between city pairs, Volpe Center staff proceeded with the development of an econometric model for accomplishing this.

Over the past year, the Volpe Center's NMI auto model has been reviewed and updated as part of an initiative sponsored by the Federal Railroad Administration (FRA) to assess the commercial feasibility of high speed ground transportation. In response to recent concerns expressed by John Harding of the FRA in his July 29th memo to Neil Moyer, the model has been revised further. With each update, the statistical robustness of the model has improved. The first update included an expansion of the data base used for estimation purposes from 38 to 55 observations, and the inclusion of an independent variable to capture the effects on travel caused when cities are major tourist attractions. The most recent changes to the model include the expansion of the data base by one observation, the replacement of the rail dummy variable with actual rail frequencies, and the inclusion of a dummy variable to capture the difficulty of driving to or using a car in Manhattan.

The succeeding sections describe steps that were taken to update the Volpe Center model from the NMI version to the first version completed for the commercial feasibility study (CFS), and further modifications that were made based on a thorough review of CALTRANS' auto trip estimates and modeling procedures. For simplification, the first commercial feasibility version is referred to in this report as the original CFS model and the more recent version as the CFS modified model. (To be able to trace the transformation of the model, the NMI version of the model is included in Appendix 1.)

METHODOLOGY

The original Volpe Center CFS auto trip model (first commercial feasibility version) was estimated using a data base with 55 observations. The data base was developed by pooling auto trip information from 10 maglev and/or high speed rail market feasibility studies that have been

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1 To more accurately describe the auto trip model, the word inter-regional has been included in the model's title. The model is intended to estimate trips from one Metropolitan Statistical Area (MSA), as defined by the U.S. Census, to another MSA.

conducted since the mid-1980's. These studies are listed below in Table 1. For consistency, 1988 was chosen as the baseline year, and auto trip, population and per capita income data were adjusted accordingly. The U.S. Census was the source for the population and income data, and Rand-McNally was the source for road miles.

Even though only a limited number of corridor studies have been conducted in the U.S., the pooled data base includes city pairs that are representational of the country's geographical and economic diversity (Table 2). The cities that constitute the city pairs vary in population, average per capita income, and economic activity. The populations and incomes for the metropolitan areas range from about .4 million to almost 18.0 million, and $14,000 to $20,000, respectively. Cities whose attractiveness (in terms of trip generation) is not necessarily dependent upon size but special activities - government and recreation - are also included in the data base. The data base also includes city pairs which are composed of different size cities (e.g., large to large, large to medium, large to small, etc.), and cities that are separated by distances ranging from 50 to 450 miles.

Table 1
CORRIDOR STUDIES

Studies	Study Sponsor
Northeast	FRA, AMTRAK
Pennsylvania	Pennsylvania High Speed Rail Commission
Texas Triangle	Texas Turnpike Authority
New York State	New York State Department of Transportation
Ohio	Ohio High Speed Rail Authority
California	Southern California Association of Governments
Florida Commission	Florida Department of Transportation
Tri-State	Illinois Department of Transportation Wisconsin Department of Transportation Minnesota Department of Transportation
Illinois - Wisconsin	Illinois Department of Transportation
California - Nevada Commission	California - Nevada High Speed Rail Commission

Table 2
CITY PAIRS USED FOR MODEL ESTIMATION

Origin	Destination	Distances
Albany*	NYC	153
Austin*	Houston	163
Boston*	Washington DC	435
Buffalo*	Albany	283
Buffalo*	Rochester	74
Buffalo*	Syracuse	152
Cleveland*	Cincinnati	247
Cleveland*	Columbus	138
Columbus*	Cincinnati	110
DFW*	Austin	191
DFW*	San Antonio	269
Houston*	DFW	242
Houston*	San Antonio	193
Los Angeles	Las Vegas	272
Los Angeles*	Sacramento	385
Los Angeles*	San Francisco	387
Madison*	Chicago	138
Madison*	Milwaukee	77
Milwaukee*	Chicago	86
Minneapolis*	Chicago	400
Minneapolis*	Madison	269
Minneapolis*	Milwaukee	329
NYC*	Baltimore	210
NYC*	Boston	211
NYC*	Philadelphia	115
NYC*	Providence	175
NYC*	Washington DC	248
Philadelphia*	Harrisburg	104
Philadelphia*	Pittsburgh	295
Philadelphia*	Washington DC	134
Philadelphia*	Baltimore	96
Pittsburgh*	Harrisburg	197
Rochester*	Albany	220
Rochester*	Syracuse	89
San Antonio*	Austin	78
Syracuse*	Albany	135
Tampa Bay	W. Palm Beach	197
Tampa Bay	Daytona Beach	138
Tampa Bay	Miami	249
Tampa Bay	Jacksonville	195
Tampa Bay	Lakeland	32
Tampa Bay*	Orlando	84
Jacksonville	Daytona Beach	90
Jacksonville	W. Palm Beach	278
Jacksonville	Miami	339
Orlando	W. Palm Beach	165
Orlando	Daytona Beach	54
Orlando	Miami	226
Orlando	Jacksonville	138
Chicago	Bloomington	135
Chicago	Springfield	197
Chicago	St. Louis	287
Bloomington	Springfield	62
Bloomington	St. Louis	158
Springfield	St. Louis	97

*Those city pairs used to estimate the version of the model used in the National Maglev Initiative.

DATA BASE REVIEW

Due to concerns recently expressed about the California observations included in the data base, a review was conducted of the source document (for these observations) to determine the reasonableness of these estimates.

The data base that was used for the original CFS model estimation has two California city pairs - Los Angeles to San Francisco and Los Angeles to Sacramento. Estimates of 1988 one-way auto (person) trips for these city pairs were obtained from a report titled, "Southern California High Speed Feasibility Study", prepared by the Southern California Association of Governments (SCAG) in 1991. Auto trip estimates that were included in the data base were 1,180,711 for Los Angeles to San Francisco, and 725,438 from Los Angeles to Sacramento.

Review of the report indicated the following:

1. The California Statewide Traffic Model (1987), developed by CALTRANS, was the source of the auto estimates.

2. SCAG only reported auto travel from the four counties in the Los Angeles metropolitan area which are members of its "region" (Los Angeles, Orange, San Bernardino, and Riverside counties) to five counties in the San Francisco metro area (San Francisco, Marin, San Mateo, Alameda and Contra Costa counties). These regional boundary definitions are not consistent with the U.S. Census' Consolidated Metropolitan Statistical Area (CMSA) definitions that were used in the Volpe model to estimate auto trip estimates. The Los Angeles CMSA contains 5 counties - Los Angeles, Orange, San Bernardino, Riverside and Ventura, and the San Francisco CMSA contains 10 counties - San Francisco, San Mateo, Santa Clara, Santa Cruz, Marin, Napa, Solano, Sonoma, Alameda and Contra Costa. This means that only a portion of the auto trips between the city pairs was represented in the data base that was used to estimate the original CFS model.

   The SCAG report does not list the counties that were used to define the Sacramento metropolitan area. It is assumed that SCAG included the four counties - Sacramento, Placer, Yolo and El Dorado, which constitute the MSA as defined by the U.S. Census.

3. SCAG also included in its report an estimate of 25,904,963 auto trips from Los Angeles and San Bernardino counties to San Diego County. Due to the extreme size of this estimate and its inconsistency with other observations included in the data base, it was not used in the original NMI and CFS model estimations (this issue is further discussed below). Table 3 lists other "comparable" city pairs and their respective observed one-way person trips. Milwaukee to Chicago probably is the most comparable city-pair; however, it is smaller in overall population and closer in distance. Its observed one way auto trips are approximately 10.7 million.

Table 3
Comparison of SCAG's Los Angeles to San Diego Auto Trip Estimate with Other Short Distance City Pair Estimates

City 1	City 2	Distance	Estimated Trips
Los Angeles	San Diego	124	25,904,963
Albany	New York City	153	907,705
Austin	Houston	163	1,088,620
Buffalo	Rochester	74	287,425
Buffalo	Syracuse	152	1,219,576
Cleveland	Columbus	138	1,664,754
Columbus	Cincinnati	110	1,645,039
Madison	Chicago	138	4,481,547
Madison	Milwaukee	77	2,283,870
Milwaukee	Chicago	86	10,651,405
New York City	Philadelphia	115	6,674,600
New York City	Providence	175	1,002,966
Philadelphia	Harrisburg	104	2,605,000
Philadelphia	Baltimore	96	2,969,970
Philadelphia	Washington, D.C.	134	1,992,690
Rochester	Syracuse	89	3,308,136
San Antonio	Austin	78	1,720,784
Syracuse	Albany	135	782,428
Tampa Bay	Daytona Beach	138	673,500
Tampa Bay	Lakeland	32	6,593,625
Jacksonville	Daytona Beach	90	1,979,750
Bloomington	Springfield	62	471,085
Bloomington	St. Louis	158	260,866
Springfield	St. Louis	97	905,770

CALIFORNIA'S ESTIMATES AND MODELING PROCEDURES

CALTRANS' Auto Trip Estimates

Recently, John Harding (FRA) indicated that CALTRANS has a 1987 auto trip matrix for all counties in the state, and that its estimate of Los Angeles to San Diego and Los Angeles to San Francisco auto trips are much higher than what the Volpe Center's (original CFS) model produced. For the Los Angeles - San Diego city pair, Harding's memo reported 1993 one-way auto person trips (based on CALTRANS' 1987 auto estimates) of 37.2 million versus a Volpe Center estimate for the year 2000 of 3.2 million.

To better understand these reported discrepancies in auto travel, the Volpe Center obtained CALTRANS' 1987 auto trip matrix. Also, in two telephone conversations with Dennis Azavedo of CALTRANS, an attempt was made to establish the following: 1) the comparability of the SCAG and CALTRANS' numbers; 2) verify the numbers in the Harding memo; 3) understand how the CALTRANS numbers were generated, and 4) determine to what extent the estimates reflect observed inter-city trips. CALTRANS also supplied the Volpe Center with two reports. One of the reports documents how the 1987 auto estimates were generated; the other one presents socioeconomic and travel data from a 1991 statewide travel survey.

Based on the conversation with Dennis Azavedo and an examination of the CALTRANS' reports, the following was determined:

1. The CALTRANS 1987 trip matrix includes all automobile trips (e.g. local, commuter, and inter-city) from county to county. No differentiation is made for inter-city trips and urban trips. Each cell includes one-way trips between each pair of counties.

2. According to CALTRANS survey results, the statewide average number of persons per auto trip is 1.58. CALTRANS uses this factor to convert vehicle trips to person trips.

3. Even though the Harding memo states that CALTRANS provided the 1993 estimates, Dennis Azavedo said that these are not his numbers and that he only provided John Harding with 1987 person trips based on CALTRANS' auto trip matrix. John Harding presumably expanded the CALTRANS 1987 auto estimates to 1993 using trip rate growth factors. The annual growth rates that were assumed by John Harding and the ones that are being used by the Volpe Center for these corridors were compared. Depending on the city pair, Harding assumed annual growth rates ranging from 2.0% to 2.3%, whereas, the Volpe Center used annual growth rates averaging about 1.6%.

4. Dennis Azavedo stated that the Volpe Center should be careful that consistent geographical units are being used to define metropolitan areas when comparing auto trip estimates that have been developed using the county flows reported in CALTRANS' trip matrix. (There is not always agreement on what counties constitute a metropolitan area. For example, Dennis Azavedo suggested that the Volpe Center consider including

Imperial County as part of the San Diego metropolitan area. According to the U.S. Census, the San Diego MSA only includes San Diego County. Similarly, Dennis Azavedo stated that the San Francisco metropolitan area is composed of nine counties; however, according to the U.S. Census, the MSA has ten counties.)

CALTRANS' Modeling Procedures

The only base year auto estimates that are available from CALTRANS are for the year 1987. These are the results of a modeling procedure that CALTRANS refers to as the Statewide Traffic Model. It estimates average daily light-duty **vehicle** trips and traffic using a three step process of trip generation, trip distribution and network assignment using the Urban Transportation Planning System software package.

The first statewide traffic model was structured and calibrated in 1970 using household and roadside interview data from 11 large scale transportation studies conducted from 1964-1970. This data were supplemented with roadside interview data collected at the state's largest points of entry. Since then, the model has been recalibrated two different times (from 1976-1978, and 1983-1985).

The documentation provided by CALTRANS is not very extensive. While the CALTRANS methods might provide reasonable estimates of within county auto trip making, there is ample reason to believe that the 1987 county-to-county auto estimates may not be a sound approximation of inter-regional travel in the state of California. The following observations can be made regarding CALTRANS' modeling procedures:

1. Documentation was not provided regarding the amount or extent of trip data that were collected to estimate the 1987 statewide model. More importantly, the documentation does not indicate to what extent survey data were split between urban and inter-city travel or how sample trip data were expanded to represent total statewide travel. There is reason to suspect that very few of the sample trips represented inter-city travel.

2. Trips are generated for the following trip purposes: home-work, home-other, home-pleasure, home-recreation, and other-other. These trip purposes imply that many of the trips accounted for in the 1987 matrix are not inter-city trips. Even though the CALTRANS report provides little information on this, it is very likely that the sample size of observed trip-making that was used for model development did not include an adequate number of longer, inter-city trips.

3. As in urban transportation modeling, the state has been divided into traffic analysis zones. For 1,495 zones, CALTRANS generated trips for five purposes using production and attraction equations. The equations were derived from multiple linear regression analysis of pooled zonal trip end and socio-economic data.

   The level of zonal aggregation in the CALTRANS' statewide effort is at the county level.

This level of aggregation can be problematic given the wide range in county sizes, and the variety of land activity and socioeconomic backgrounds of people residing in a county. The problem of aggregation can be particularly acute when attempting to generate the productions and attractions for urban counties, such as Los Angeles, Orange and San Diego.

Also, the quality of the trip production and attraction functions are dependent upon the extensiveness of the trip making data that are available for each of the counties, and the extent that they explain the trip-making characteristics of the counties. Given the variability in the land and socioeconomic activity from one county to another, developing statistically valid functions to be applied statewide could be difficult. Also, it is not unusual for these types of functions to generate higher levels of trips from counties which are less densely populated. According to the CALTRANS' documentation, adjustments needed to be made to correct for over-estimating trips from rural zones to larger urban zones.

4. The documentation indicates that the trip production and attraction equations are calibrated so that trip length frequency distributions closely match those from the combined urban and roadside interviews. Thus, if most of the trip observations are for urban trips as opposed to inter-city trips, the trip length frequency distribution for the 1987 matrix will be heavily weighted toward short trips. As a result, the errors in predicting long inter-city trips will be magnified (i.e., these trips are represented by the tail of the trip length/frequency distribution.)

   This appears to be the case since the 1987 (California) statewide traffic model trip length frequencies for each of the five trip purposes range on average from 5.90 miles to 12.69 miles (Table 4). The mean trip length statewide is 7.50 miles. The frequencies, which are displayed graphically on a succeeding page (obtained from the CALTRANS report on the 1987 statewide traffic model), indicate that most of the observed trips do not exceed 40 miles for the different trip purposes. In fact, for each of the trip purposes, it appears that less than one percent of the trips exceeded 40 miles.

Table 4
Trip Lengths (In Miles) by Trip Purpose
from
1987 California Statewide Traffic Model

Trip Purposes	Mean Trip Lengths	Median Trip Lengths
Home - Work	10.17	6.85
Home - Pleasure	10.09	5.36
Home - Other	5.90	3.44
Recreation	12.69	6.56
Other - Other	6.55	3.70
Total	7.50	4.18

CALTRANS 1991 STATEWIDE AUTO TRAVEL SURVEY

In 1991, CALTRANS conducted a statewide travel survey which consisted of approximately 13,500 household interviews for weekday travel and 900 interviews for weekend travel. The survey was intended to provide a current snapshot of both regional and inter-regional travel patterns, and was structured to capture the travel behavior of the participants over one day. CALTRANS is currently recalibrating its statewide traffic model using these survey results and a more up-to-date baseline estimate of statewide auto trips will be available in the future. As of this time, the up-to-date estimates have not been published. It is also important to point out that CALTRANS 1991 survey is obviously unrelated to the 1987 auto trip estimates discussed above.

In his memo, John Harding implies that the 1991 survey is the basis for the current statewide estimates that are available from CALTRANS and the estimates of inter-regional travel that he presented. According to CALTRANS, he was only given 1987 data.

Even though this 1991 survey is not directly relevant to this discussion, it does provide a number of interesting insights. The CALTRANS report on the 1991 statewide survey includes a copy of the 24 hour travel diary that members of a household were asked to fill out. Since it is a diary of trip-making over a particular day, it is not designed to capture the inter-regional trip making behavior of a household for an extended period of time (for example, a year). Its design is such that the vast majority of trips that a respondent would record would be of a local nature (home, work, school, shopping and other). In addition, the survey's focus was not solely on auto travel. Respondents were asked to record trips made by bus, train, airplane and walking.

If the intent was to better understand inter-regional automobile trip making within the state, a more direct approach would have been to ask participants about the trips that they have made by automobile over the last year that are greater than 50 miles. For example, this is the approach that was used in the northeast corridor study (conducted by the FRA and AMTRAK) which is one of the sources of auto travel used to estimate the Volpe Center's model.

According to the 1992 National Personal Transportation Survey (NPTS), the average person takes 4.7 non-commuting trips greater than 50 miles per year. This means that the probability of the 1991 California one day statewide survey capturing examples of inter-city or inter-regional is approximately 1.3 percent (4.7 trips/year ÷ 365 days/year). That is, approximately 190 of the households that were interviewed probably reported inter-city trips.

NATIONAL PERSONAL TRANSPORTATION STUDY BASED ESTIMATES OF AUTO TRIPS BETWEEN SAN DIEGO AND LOS ANGELES

Sufficient data are available in the 1992 National Personal Transportation Survey (NPTS) to construct an approximate but plausible estimate of intercity non-commuter auto trips between the San Diego MSA and the Los Angeles CMSA. To do this, a file was constructed from the revised version of the NPTS person-trip file, which included total trips by mode, distance block, trip purpose, destination MSA and several other characteristics.

The 1992 NPTS has 1.2 billion one-way trips of length 50 miles or greater. (Commuter trips are excluded from this total.) The U.S. population in that year was 254 million, meaning that the average person took 4.7 non-commuting trips of length greater than 50 miles per year. Applying this to the Los Angeles and San Diego MSA's, the 15 million people in the Los Angeles CMSA would be expected to take 70 million such trips, and the 2.5 million in the San Diego MSA would be expected to take about 12 million (these are trips to many different destinations greater than 50 miles).

The 1.2 billion trips can be divided among the distance blocks 50-74 miles, 75-99, 100-149, 150-199 etc. From this, it turns out that, of the 4.7 trips the average person takes each year, 1.0 is in the 50-74 block, 0.9 in the 75-99 block, 1.1 in the 100-149 block, with the rest in longer blocks. Because the Los Angeles and San Diego MSA's are large, it is plausible to assume that most of the trips in the 50-74 blocks are intra-MSA trips, and that the San Diego-Los Angeles trips come out of the 2.0 trips per year in the 75-149 mile range. For Los Angeles travellers, Santa Barbara and Bakersfield compete with San Diego as major destinations in this trip distance range, as well as, trips to non-MSA areas. Based on percentages derived from the Volpe Center's auto model, perhaps 40% (0.8 trips per year) from Los Angeles will be to San Diego. For San Diego, Tijuana is the only competing metropolitan area in the proper range; perhaps 90% (1.8 trips per year) are to Los Angeles.

The NPTS also includes destination data by MSA. There are 45 million trips whose destination is the Los Angeles CMSA, and 20 million of these are in the 75-149 mile range. There are 15 million trips to the San Diego MSA, with 8 million in the 75-149 mile range. Assuming, at 90%

of the trips to Los Angeles come from San Diego, and 40% of the trips to San Diego come from Los Angeles, a revised estimate of Los angeles to San Diego auto trips is:

$$20m*.4 + 8m*.9 = 15.2 \text{ million auto trips.}$$

As a result, the CFS model was re-estimated using this estimate of auto trips.

MODIFICATION OF VOLPE CENTER'S DATA BASE AND MODEL

Several modifications were made to the Volpe Center's data base and model resulting in a final modified CFS auto model. Besides adding the Los Angeles to San Diego observation to the data base, the auto trip observations in the data base were modified to better reflect the U.S. Census' definition of CMSAs for Los Angeles and San Francisco, and new explanatory variables were tested. These modifications are described in greater detail below.

- **Modification of Auto Trip Observations.** The observed auto trips for Los Angeles to San Francisco and Los Angeles to Sacramento were adjusted to reflect the U.S. Census' definitions of metropolitan areas. The new auto trip observations equal the auto flows from each of the counties in the metropolitan areas reported in CALTRANS' trip matrix. The Los Angeles to San Francisco observation increased from 1,180,711 one-way trips to 2,793,619, and the Los Angeles to Sacramento observation decreased from 725,438 to 663,844.

- **Inclusion of an Additional Observation.** Considering the importance of the Los Angeles-San Diego city pair, the observation was added to the data base. The estimate of 15.2 million one-way auto trips, which was based on the NPTS analysis described above, was used.

- **New Explanatory Variables.** Due to concerns expressed about the disparity in auto ownership and travel behavior in different parts of the U.S., a number of modifications to the model's explanatory variables were tested. These tests and recommended modifications to the model are described below.

    1. The dummy variable for frequent rail service (more than 3 trains per day) between cities was replaced with a continuous variable using actual rail frequencies for cities with more than 3 trains per day. By doing this, frequent rail service is no longer treated in a generalized fashion for all parts of the U.S. Creating this sensitivity is significant since rail service varies tremendously between city pairs, with the northeast cities having the highest service levels. Certain city pairs, such as New York to Philadelphia and New York to Washington, D.C., are served by as many as 34 to 37 trains per day, while the maximum California rail service is 11 trains per day in the Los Angeles to San Diego corridor.

2. A dummy variable was tested to determine whether the propensity to drive in California (as well as Texas and Florida) is higher than in other states. This test was done for California city pairs only, and with city pairs located in Texas and Florida. In each instance, the variable was not statistically significant. This implies that the trip data for California is explained as well by model variables as is the trip data for other city-pairs.

3. Since driving to or having a car in Manhattan entails unusual levels of congestion and high parking costs, a dummy variable was tested for all city pairs that include New York City. The inclusion of this dummy proved to be statistically significant.

MODEL SPECIFICATIONS

The original and modified CFS auto models are presented below along with the t-statistics for each of the coefficients. The R^2 improved slightly, increasing from .78 to .80. In addition, the constant, and the total income, distance and fun coefficients increased. The increase in the total income coefficient from .42 to .53 will contribute to higher future year auto trip estimates.

Original CFS Model

$\ln T_{ij\,auto} = -4.07 + .42\ln(PI_i * PI_j) - 1.75\ln D_{ij} + .97F_{ij} - .59R_{ij}$

(t statistics) (9.2) (-12.1) (4.5) (-3.4)

Number of Observations = 55

R-square = .78

where

T_{ijauto} = one way auto trips between city pairs (trips are in thousands)

PI_i = (C)MSA population * (C)MSA average personal per capita income for origin city (total personal per capita income)

PI_j = (C)MSA population * (C)MSA average personal per capita income for destination city (total personal per capita income)

D_{ij} = road mile distance between the city pairs

F_{ij} = dummy variable for cities which are major tourist attractions (e.g., Las Vegas and Orlando)

R_{ij} = dummy variable defining frequent rail service

Modified CFS Model

$$\ln T_{ij\,auto} = -8.84 + .53\ln(PI_i{*}PI_j) - 1.87\ln D_{ij} + .98F_{ij} - .02R_{ij} - .48N_{ij}$$

(t statistics) (10.0) (-12.7) (4.7) (-2.9) (-1.8)

Number of Observations = 56

R-square = .80

where

T_{ijauto} = one way auto trips between city pairs (trips are in thousands)

PI_i = (C)MSA population * (C)MSA average personal per capita income for origin city (total personal per capita income)

PI_j = (C)MSA population * (C)MSA average personal per capita income for destination city (total personal per capita income)

D_{ij} = road mile distance between the city pairs

F_{ij} = dummy variable for cities which are major tourist attractions (e.g., Las Vegas and Orlando)

R_{ij} = actual rail frequencies for city pairs served by more than 3 trains per day

N_{ij} = dummy variable for all city pairs that include New York City

Additional Consistency Testing

To see if the CALTRANS' estimate of 31 million one-way auto trip between Los Angeles and San Diego (obtained from CALTRANS' 1987 auto trip matrix) was consistent with the other data and model parameters estimated without the observation, a special set of regression equations were estimated. With the higher observation included, the model's significance declined and a very large residual was obtained for the Los Angeles to San Diego observation. These results indicate that the annual 1987 CALTRANS' Los Angeles to San Diego auto trip estimate is not consistent with other auto trip estimates used for the estimation of the Volpe Center's auto model.

APPENDIX 1

THE VOLPE CENTER'S INTER-REGIONAL AUTO MODEL NATIONAL MAGLEV INITIATIVE

$\ln T_{ij\,auto} = -2.47 + .38\ln(PI_i * PI_j) - 1.71\ln D_{ij} - .48R_{ij}$

(t statistics) (5.7) (-9.9) (-2.2)

Number of Observations = 38

R-square = .75

where

T_{ijauto} = one way auto trips between city pairs (trips are in thousands)

PI_i = CMSA population * CMSA average personal per capita income for origin city

PI_j = CMSA population * CMSA average personal per capita income for destination city

D_{ij} = Road mile distance between the city pairs

R_{ij} = Dummy variable defining frequent rail service between city pairs ((A one was assigned to city pairs with daily rail frequencies in 1988 greater than 3; and a zero was assigned to city pairs with frequencies ranging from 0 to 3.)