A5 - COMPASS™ Model

1. *COMPASS*™ Model Calibration

The *COMPASS*™ Model System is a flexible multimodal demand-forecasting tool that provides comparative evaluations of alternative socioeconomic and network scenarios. It also allows input variables to be modified to test the sensitivity of demand to various parameters such as elasticities, values of time, and values of frequency. This section describes in detail the model methodology and process using in the Ohio and Lake Erie Regional Rail (Cleveland Hub) Study.

1.1 Description of the *COMPASS*™ Model System

The *COMPASS*™ model is structured on three principal models: Total Demand Model, Hierarchical Modal Split Model, and Induced Demand Model. For this study, these three models were calibrated separately for two trip purposes, i.e., *Business* and *Other* (commuter, personal, and social). Moreover, since the behavior of short-distance trip making is significantly different from long-distance trip making, the database was segmented by distance, and independent models were calibrated for both long and short-distance trips. For each market segment, the models were calibrated on origin-destination trip data, network characteristics and base year socioeconomic data.

The models are calibrated on the base year data. In applying the models for forecasting, an incremental approach known as the "pivot point" method is used. By applying model growth rates to the base data observations, the "pivot point" method is able to preserve the unique travel flows present in the base data that are not captured by the model variables. Details on how this method is implemented are described below.

1.2 Total Demand Model

The Total Demand Model, shown in Equation 1, provides a mechanism for assessing overall growth in the travel market.

Equation 1:

$$T_{ijp} = e^{\beta 0p}(SE_{ijp})^{\beta 1p} e^{\beta 2p\ Uijp}$$

Where,

T_{ijp} = Number of trips between zones *i* and *j* for trip purpose *p*
SE_{ijp} = Socioeconomic variables for zones *i* and *j* for trip purpose *p*
U_{ijp} = Total utility of the transportation system for zones *i* to *j* for trip purpose *p*
$\beta_{0p}, \beta_{1p}, \beta_{2p}$ = Coefficients for trip purpose *p*

As shown in Equation 1, the total number of trips between any two zones for all modes of travel, segmented by trip purpose, is a function of the socioeconomic characteristics of the zones and the total utility of the transportation system that exists between the two zones. For this study, trip purposes include *Business* and *Other*, and socioeconomic characteristics consist of population, employment and per capita income. The utility function provides a logical and intuitively sound method of assigning a value to the travel opportunities provided by the overall transportation system.

In the Total Demand Model, the utility function provides a measure of the quality of the transportation system in terms of the times, costs, reliability and level of service provided by all modes for a given trip purpose. The Total Demand Model equation may be interpreted as meaning that travel between zones will increase as socioeconomic factors such as population and income rise or as the utility (or quality) of the transportation system is improved by providing new facilities and services that reduce travel times and costs. The Total Demand Model can therefore be used to evaluate the effect of changes in both socioeconomic and travel characteristics on the total demand for travel.

1.2.1 Socioeconomic Variables

The socioeconomic variables in the Total Demand Model show the impact of economic growth on travel demand. The *COMPASS*™ Model System, in line with most intercity modeling systems, uses three variables (population, employment and per capita income) to represent the socioeconomic characteristics of a zone. Different combinations were tested in the calibration process and it was found, as is typically found elsewhere, that the most reasonable and stable relationships consists of the following formulations:

Trip Purpose	*Socioeconomic Variable*
Business	$E_i E_j (I_i + I_j) / 2$
Other	$P_i P_j (I_i + I_j) / 2$

The business formulation consists of a product of employment in the origin zone, employment in the destination zone, and the average per capita income of the two zones. Since business trips are usually made between places of work, the presence of employment in the formulation is reasonable. The *Other* formulation consists of a product of population in the origin zone, population in the destination zone and the average per capita income of the two zones. *Other* trips encompass many types of trips, but the majority is home-based and thus, greater volumes of trips are expected from zones from higher population.

1.2.2 Travel Utility

Estimates of travel utility for a transportation network are generated as a function of generalized cost (GC), as shown in Equation 2:

Equation 2:

$$U_{ijp} = f(GC_{ijp})$$

Where,

GC_{ijp} = Generalized Cost of travel between zones *i* and *j* for trip purpose *p*

Because the generalized cost variable is used to estimate the impact of improvements in the transportation system on the overall level of trip making, it needs to incorporate all the key modal attributes that affect an individual's decision to make trips. For the public modes (i.e., rail, bus and air), the generalized cost of travel includes all aspects of travel time (access, egress, in-vehicle times), travel cost (fares, tolls, parking charges), schedule convenience (frequency of service, convenience of arrival/departure times) and reliability.

The generalized cost of travel is typically defined in travel time (*i.*e., minutes) rather than dollars. Costs are converted to time by applying appropriate conversion factors, as shown in Equation 3. The generalized cost (GC) of travel between zones i and j for mode m and trip purpose p is calculated as follows:

Equation 3:

$$GC_{ijmp} = TT_{ijm} + \frac{TC_{ijmp}}{VOT_{mp}} + \frac{VOF_{mp}OH}{VOT_{mp}F_{ijm}C_{ijm}} + \frac{VOR_{mp}\exp(-OTP_{ijm})}{VOT_{mp}}$$

Where,

TT_{ijm} = Travel Time between zones *i* and *j* for mode *m* (in-vehicle time + station wait time + connection wait time + access/egress time + interchange penalty), with waiting, connect and access/egress time multiplied by a factor (greater than 1) to account for the additional disutility felt by travelers for these activities

TC_{ijmp} = Travel Cost between zones *i* and *j* for mode *m* and trip purpose *p* (fare + access/egress cost for public modes, operating costs + tolls for auto)

VOT_{mp} = Value of Time for mode *m* and trip purpose *p*

VOF_{mp} = Value of Frequency for mode *m* and trip purpose *p*

VOR_{mp} = Value of Reliability for mode *m* and trip purpose *p*

F_{ijm} = Frequency in departures per week between zones *i* and *j* for mode *m*

C_{ijm} = Convenience factor of schedule times for travel between zones *i* and *j* for mode *m*

OTP_{ijm} = On-time performance for travel between zones *i* and *j* for mode *m*

OH = Operating hours per week

Station wait time is the time spent at the station before departure and after arrival. Air travel generally has higher wait times because of security procedures at the airport, baggage checking, and the difficulties of loading a plane. Air trips were assigned wait times of 45 minutes while rail trips were assigned wait times of 30 minutes and bus trips were assigned wait times of 20 minutes. On trips with connections, there would be additional wait times incurred at the connecting station. Wait times are weighted higher than in-vehicle time in the generalized cost formula to reflect their higher disutility as found from previous studies. Wait times are weighted 70 percent higher than in-vehicle time for *Business* trips and 90 percent higher for *Other* trips.

Similarly, access/egress time has a higher disutility than in-vehicle time. Access time tends to be more stressful for the traveler than in-vehicle time because of the uncertainty created by trying to catch the flight or train. Based on previous work, access time is weighted 30 percent higher than in-vehicle time for air travel and 80 percent higher for rail and bus travel.

TEMS has found from past studies that the physical act of transferring trains (or buses or planes) has a negative impact beyond the times involved. To account for this disutility, interchanges are penalized time equivalents. For both air and rail travel, each interchange for a trip results in 40 minutes being added to the *Business* generalized cost and 30 minutes being added to the *Other* generalized cost. For bus travel, the interchange penalties are 20 minutes and 15 minutes for *Business* and *Other*, respectively.

The third term in the generalized cost function converts the frequency attribute into time units. Operating hours divided by frequency is a measure of the headway or time between departures. Tradeoffs are made in the stated preference surveys resulting in the value of frequencies on this measure. Although there may appear to some double counting because the station wait time in the first term of the generalized cost function is included in this headway measure, it is not the headway time itself that is being added to the generalized cost. The third term represents the impact of perceived frequency valuations on generalized cost. TEMS has found it very convenient to measure this impact as a function of the headway.

The fourth term of the generalized cost function is a measure of the value placed on reliability of the mode. Reliability statistics in the form of on-time performance (i.e., the fraction of trips considered to be on time) were obtained for the rail and air modes only. The negative exponential form of the reliability term implies that improvements from low levels of reliability have slightly higher impacts than similar improvements from higher levels of reliability.

1.2.3 Calibration of the Total Demand Model

In order to calibrate the Total Demand Model, the coefficients are estimated using linear regression techniques. Equation 1, the equation for the Total Demand Model, is transformed by taking the natural logarithm of both sides, as shown in Equation 4:

Equation 4:

$$\log(T_{ijp}) = \beta_{0p} + \beta_{1p}\log(SE_{ijp}) + \beta_{2p}(U_{ijp})$$

Equation 4 provides the linear specification of the model necessary for regression analysis.

The segmentation of the database by trip purpose and trip length resulted in four sets of models. Trips that would cover more than 145 miles are considered long-distance trips. This cutoff was chosen because travel behavior switches significantly around this level, with travelers considering faster modes such as air and high-speed rail over the automobile. In the base data, the average trip length for the short-distance model is approximately 80 miles, while the average trip length for the long-distance model is approximately 310 miles. The results of the calibration for the Total Demand Models are displayed in Exhibit 1.

Exhibit 1: Total Demand Model Coefficients [1]

Long-Distance Trips (*trip length greater than 145 miles*)

Business $\log(T_{ij}) = -2.52 + \underset{(91)}{0.421\,SE_{ij}} + \underset{(65)}{0.987\,U_{ij}}$ $R^2=0.71$

where $U_{ij} = \log[\exp(-0.437 + 3.718\,U_{Pub}) + \exp(-0.00166\,GC_{Car})]$

Other $\log(T_{ij}) = -2.44 + \underset{(125)}{0.403\,SE_{ij}} + \underset{(76)}{0.539\,U_{ij}}$ $R^2=0.70$

where $U_{ij} = \log[\exp(-0.532 + 3.415\,U_{Pub}) + \exp(-0.00219\,GC_{Car})]$

Short-Distance Trips (*trip length less than 145 miles*)

Business $\log(T_{ij}) = -0.47 + \underset{(19)}{0.396\,SE_{ij}} + \underset{(19)}{1.388\,U_{ij}}$ $R^2=0.72$

where $U_{ij} = \log[\exp(-4.482 + 2.765\,U_{Pub}) + \exp(-0.00787\,GC_{Car})]$

Other $\log(T_{ij}) = -0.44 + \underset{(15)}{0.390\,SE_{ij}} + \underset{(13)}{1.262\,U_{ij}}$ $R^2=0.70$

where $U_{ij} = \log[\exp(-2.852 + 1.430\,U_{Pub}) + \exp(-0.00380\,GC_{Car})]$

[1] *t-statistics are given in parentheses.*

In evaluating the validity of a statistical calibration, there are two key statistical measures: *t*-statistics and R^2. The *t*-statistics are a measure of the significance of the model's coefficients; values of 1.95 and above are considered "good" and imply that the variable has significant explanatory power in estimating the level of trips. The R^2 is a statistical measure of the "goodness of fit" of the model to the data; any data point that deviates from the model will reduce this measure. It has a range from 0 to a perfect 1, with 0.4 and above considered "good" for large data sets.

Based on these two measures, the total demand calibrations are good. The *t*-statistics are very high, aided by the large size of the Midwest data set. There are roughly five times as many long-distance observations as short-distance observations, resulting in higher *t*-statistics for the long- distance models. The R^2 values imply very good fits of the equations to the data.

As shown in Exhibit 1, the socioeconomic elasticity values for the Total Demand Model are close to 0.4, meaning that each one percent growth in the socioeconomic term generates approximately a 0.4 percent growth in trips. Since each component of the socioeconomic term will have this elasticity, a one percent increase in population (or employment) of every zone combined with a one percent increase in income will result in a 0.8 percent growth in trips.

The coefficient on the utility term is not exactly elastic, but it can be used as an approximation. Thus, the transportation system or network utility elasticity is higher for short-distance trips than long-distance trips, with each one percent improvement in network utility or quality as measured by generalized cost (i.e., travel times or costs) generating approximately a 0.7 percent increase for long-distance trips and a 1.3 percent increase for short trips. The higher elasticity on short trips is partly a result of the scale of the generalized costs. For short trips, a 30-minute improvement would be more meaningful than the same time improvement on long-distance trips, reflecting in the higher elasticity on the short-distance model.

1.2.4 Incremental Form of the Total Demand Model

The calibrated Total Demand Models could be used to estimate the total travel market for any zone pair using the population, employment, per capita income, and the total utility of all the modes. However, there would be significant differences between estimated and observed levels of trip making for many zone pairs despite the good fit of the models to the data. To preserve the unique travel patterns contained in the base data, the incremental approach or "pivot point" method is used for forecasting. In the incremental approach, the base travel data assembled in the database are used as pivot points, and forecasts are made by applying trends to the base data. The total demand equation as described in Equation 1 can be rewritten into the following incremental form that can be used for forecasting (Equation 5):

Equation 5:

$$\frac{T_{ijp}^{f}}{T_{ijp}^{b}} = \left(\frac{SE_{ijp}^{f}}{SE_{ijp}^{b}}\right)^{\beta_{1p}} \exp(\beta_{2p}\ (U_{ijp}^{f} - U_{ijp}^{b}))$$

Where,

T^f_{ijp} = Number of Trips between zones *i* and *j* for trip purpose *p* in forecast year *f*

T^f_{ijp} = Number of Trips between zones *i* and *j* for trip purpose *p* in base year *b*

SE^f_{ijp} = Socioeconomic variables for zones *i* and *j* for trip purpose *p* in forecast year *f*

SE^b_{ijp} = Socioeconomic variables for zones *i* and *j* for trip purpose *p* in base year *b*

U^f_{ijp} = Total utility of the transportation system for zones *i* to *j* for trip purpose *p* in forecast year *f*

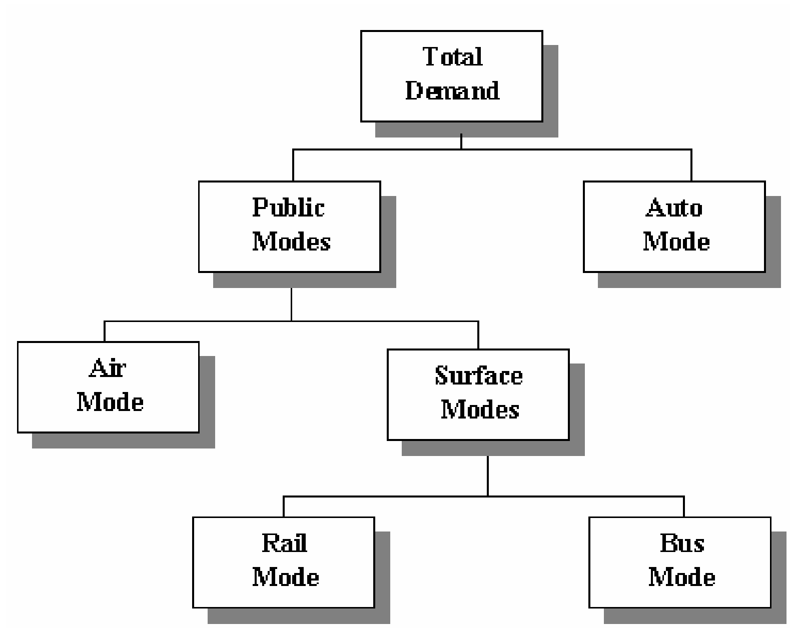
U^{b}_{ijp} = Total utility of the transportation system for zones i to j for trip purpose p in base year b

In the incremental form, the constant term disappears and only the elasticities are important.

1.3 Hierarchical Modal Split Model

The role of the Hierarchical Modal Split Model is to estimate relative modal shares, given the Total Demand Model estimate of the total market. The relative modal shares are derived by comparing the relative levels of service offered by each of the travel modes. The *COMPASS*™ Hierarchical Modal Split Model uses a nested logit structure, which has been adapted to model the intercity modal choices available in the study area. As shown in Exhibit 2, three levels of binary choice are calibrated.

Exhibit 2: Hierarchical Structure of the Modal Split Model



The main feature of the Hierarchical Modal Split Model structure is the increasing commonality of travel characteristics as the structure descends. The first level of the hierarchy separates private auto travel – with its spontaneous frequency, low access/egress times, low costs and highly personalized characteristics – from the public modes. The second level of the structure separates air – the fastest, most expensive and perhaps most frequent and comfortable public mode – from the rail and bus surface modes. The lowest level of the hierarchy separates rail, a potentially faster, more reliable, and more comfortable mode, from the bus mode.

1.3.1 Form of the Hierarchical Modal Split Model

To assess modal split behavior, the logsum utility function, which is derived from travel utility theory, has been adopted. As the modal split hierarchy ascends, the logsum utility values are derived by combining the generalized costs of travel. Advantages of the logsum utility approach are 1) the introduction of a new mode will increase the overall utility of travel, and 2) a new mode can readily be incorporated into the Hierarchical Modal Split Model, even if it were not included in the base-year calibration.

As only two choices exist at each level of the modal split hierarchical structure, a Binary Logit Model is used, as shown in Equation 6:

Equation 6: $$P_{ijmp} = \frac{\exp(U_{ijmp}/\rho)}{\exp(U_{ijmp}/\rho) + \exp(U_{ijnp}/\rho)}$$

Where,

P_{ijmp} = Percentage of trips between zones *i* and *j* by mode *m* for trip purpose *p*

U_{ijmp}, U_{ijnp} = Utility functions of modes *m* and *n* between zones *i* and *j* for trip purpose i

ρ is called the nesting coefficient

In Equation 6, the utility of travel between zones *i* and *j* by mode *m* for trip purpose *p* is a function of the generalized cost of travel. Where mode *m* is a composite mode (e.g., the surface modes in the third level of the Modal Split Model hierarchy, which consist of the rail and bus modes), the utility of travel, as described below, is derived from the utility of the two or more modes it represents.

1.3.2 Utility of Composite Modes

Where modes are combined, as in the upper levels of the modal split hierarchy, it is essential to be able to measure the "inclusive value" of the composite mode, e.g., how the combined utility for bus and rail compares with the utility for bus or rail alone. The combined utility is more than the utility of either of the modes alone, but it is not simply equal to the sum of the utilities of the two modes. A realistic approach to solving this problem, which is consistent with utility theory and the logit model, is to use the logsum function. As the name logsum suggests, the utility of a composite mode is defined as the natural logarithm of the sum of the utilities of the component modes. In combining the utility of separate modes, the logsum function provides a reasonable proportional increase in utility that is less than the combined utilities of the two modes, but reflects the value of having two or more modes available to the traveler. For example:

Suppose

Utility of Rail or $U_{rail} = \alpha + \beta_0 GC_{rail}$

Utility of Bus or $U_{bus} = \beta_1 GC_{bus}$

Then

Inclusive Utility of Surface Modes, or $U_{surface} = \log(e^{Urail} + e^{Ubus})$

Improvements in either rail or bus would result in improvements to the inclusive utility of the surface modes.

In a nested binary logit model, the calibrated coefficients associated with the inclusive values of composite modes are the *nesting coefficients* and take on special meaning. If one of these coefficients is equal to 1, then that level of the hierarchical model collapses and two levels of the hierarchy essentially become 1. At this point, the Hierarchical Modal Split Model is a multinomial logit model that is analyzing three or more modes, i.e., all the modes comprising the composite mode as well as the other modes in that level of the hierarchy. If one of the coefficients is greater than 1, then the hierarchy has been incorrectly specified and counterintuitive forecasts will result. Because of the assumptions behind the Hierarchical Modal Split Model, the coefficients must decrease as the modal split hierarchy is ascended or counterintuitive results will occur. Thus, the coefficients provide a check on whether the Modal Split Model hierarchy has been specified correctly.

1.3.3 Calibration of the Hierarchical Modal Split Model

Working from the bottom of the hierarchy up to the top, the first analysis is that of the rail mode versus the bus mode. As shown in Exhibit 3, the model was effectively calibrated for the two trip purposes and the two trip lengths, with reasonable parameters and R^2 and t values. All the coefficients have the correct signs such that demand increases or decreases in the correct direction as travel times or costs are increased or decreased, and all the coefficients appear to be reasonable in terms of the size of their impact. Rail travelers are more sensitive than bus travelers are to time and cost. This is as expected, given the general attitude that travelers, and in particular business travelers, have toward the bus mode. The higher coefficients on the short-distance models are partly due to the scale effect where the same time or cost improvements would be more meaningful on shorter trips.

Exhibit 3: Rail versus Bus Modal Split Model Coefficients [1]

Long-Distance Trips (*trip length greater than 145 miles*)

Business	$\log(P_{Rail}/P_{Bus})$ =	1.340	- 0.00109 GC_{Rail} + (37)	0.000451 GC_{Bus} (16)	R^2=0.44
Other	$\log(P_{Rail}/P_{Bus})$ =	0.675	- 0.00136 GC_{Rail} + (66)	0.000494 GC_{Bus} (27)	R^2=0.55

Short-Distance Trips (*trip length less than 145 miles*)

Business	$\log(P_{Rail}/P_{Bus})$ =	2.295	- 0.00224 GC_{Rail} + (18)	0.000592 GC_{Bus} (6)	R^2=0.50
Other	$\log(P_{Rail}/P_{Bus})$ =	1.098	- 0.00230 GC_{Rail} + (17)	0.000165 GC_{Bus} (3)	R^2=0.46

[1] *t-statistics are given in parentheses.*

The constant term in each equation indicates the degree of bias towards one mode or the other. Since the terms are positive in all the market segments, there is a bias towards rail travel that is not explained by the variables (e.g., times, costs, frequencies, reliability) used to model the modes. As expected, this bias is larger for business travelers who tend to have very negative perceptions of intercity bus.

For the second level of the hierarchy, the analysis is of the surface modes (i.e., rail and bus) versus air. Accordingly, the utility of the surface modes is obtained by deriving the logsum of the utilities of rail and bus. As shown in Exhibit 4, the model calibrations for both trip purposes are all statistically significant, with good R^2 and t values and reasonable parameters. As indicated by the air coefficients, short-distance travelers are less sensitive to changes in the air costs than long-distance travelers are. One explanation is some short-distance air trips are special trips responding to personal or business emergencies and, thus, are cost insensitive. As indicated by the constant terms, there is a large bias towards air travel for long-distance trips. However, for short trips, there is only a small bias towards air for both *Business* and *Other* travelers.

Exhibit 4: Surface versus Air Modal Split Model Coefficients [(1)]

Long-Distance Trips (*trip length greater than 145 miles*)

Business $\log(P_{Surf}/P_{Air}) = -3.260 + \underset{(78)}{2.786}\, U_{Surf} + \underset{(79)}{0.00184}\, GC_{Air}$ $R^2=0.56$

where $U_{Surf} = \log[\exp(1.340 - 0.00109\, GC_{Rail}) + \exp(-0.000451\, GC_{Bus})]$

Other $\log(P_{Surf}/P_{Air}) = -1.520 + \underset{(102)}{3.284}\, U_{Surf} + \underset{(97)}{0.00210}\, GC_{Air}$ $R^2=0.56$

where $U_{Surf} = \log[\exp(0.675 - 0.00136\, GC_{Rail}) + \exp(-0.000494\, GC_{Bus})]$

Short-Distance Trips (*trip length less than 145 miles*)

Business $\log(P_{Surf}/P_{Air}) = -1.450 + \underset{(21)}{3.981}\, U_{Surf} + \underset{(4)}{0.000418}\, GC_{Air}$ $R^2=0.62$

where $U_{Surf} = \log[\exp(2.295 - 0.00224\, GC_{Rail}) + \exp(-0.000592\, GC_{Bus})]$

Other $\log(P_{Surf}/P_{Air}) = -0.927 + \underset{(19)}{6.853}\, U_{Surf} + \underset{(9)}{0.000990}\, GC_{Air}$ $R^2=0.55$

where $U_{Surf} = \log[\exp(1.098 - 0.00230\, GC_{Rail}) + \exp(-0.000165\, GC_{Bus})]$

(1) *t-statistics are given in parentheses.*

The analysis for the top level of the hierarchy is of auto versus the public modes. The utility of the public modes is obtained by deriving the logsum of the utilities of the air, rail and bus modes.

As shown in Exhibit 5, the model calibrations for both trip purposes are all statistically significant, with good R^2 and *t* values and reasonable parameters in most cases. A reason for why the R^2 value for the other, short-distance model is a bit lower than in the rest of the model is due to the fact that local transit trips are not included in the public trip database, causing some of the observations to deviate significantly from the model equation. The constant terms show that there is a bias towards the auto mode with the bias increasing with shorter trip length.

Exhibit 5: Public versus Auto Hierarchical Modal Split Model Coefficients [(1)]

Long-Distance Trips (*trip length greater than 145 miles*)

Business $\log(P_{Pub}/P_{Auto}) = -0.437 + 3.718\ U_{Pub} + 0.00166\ GC_{Auto}$ R^2=0.71
(110) (96)
where $U_{Pub} = \log[\exp(-3.26 + 2.786\ U_{Surf}) + \exp(-0.00184\ GC_{Air})]$

Other $(P_{Pub}/P_{Auto}) = -0.532 + 3.415\ U_{Pub} + 0.00219\ GC_{Auto}$ R^2=0.54
(106) (107)
where $U_{Pub} = \log[\exp(-1.52 + 3.284\ U_{Surf}) + \exp(-0.00210\ GC_{Air})]$

Short-Distance Trips (*trip length less than 145 miles*)

Business $\log(P_{Pub}/P_{Auto}) = -4.482 + 2.765\ U_{Pub} + 0.00787\ GC_{Auto}$ R^2=0.55
(9) (19)
where $U_{Pub} = \log[\exp(-1.45 + 3.981\ U_{Surf}) + \exp(-0.000418\ GC_{Air})]$

Other $\log(P_{Pub}/P_{Auto}) = -2.852 + 1.430\ U_{Pub} + 0.00380\ GC_{Auto}$ R^2=0.44
(10) (13)
where $U_{Pub} = \log[\exp(-0.927 + 6.853\ U_{Surf}) + \exp(-0.00099\ GC_{Air})]$

[(1)] *t-statistics are given in parentheses.*

1.3.4 Incremental Form of the Modal Split Model

Using the same reasoning as previously described, the modal split models are applied incrementally to the base data rather than imposing the model estimated modal shares. Different regions of the corridor may have certain biases toward one form of travel over another and these differences cannot be captured with a single model for the entire Cleveland Hub System. Using the "pivot point" method, many of these differences can be retained. To apply the modal split models incrementally, the following reformulation of the hierarchical modal split models is used (Equation 7):

Equation 7:

$$\frac{\left(\frac{P_A^f}{P_B^f}\right)}{\left(\frac{P_A^b}{P_B^b}\right)} = e^{\beta(GC_A^f - GC_B^b) + \gamma(GC_B^f - GC_B^b)}$$

For hierarchical modal split models that involve composite utilities instead of generalized costs, the composite utilities would be used in the above formula in place of generalized costs. Once again, the constant term is not used and the drivers for modal shifts are changed in generalized cost from base conditions.

Another consequence of the pivot point method is that extreme changes from current trip-making levels and current modal shares are rare. Thus, since very few short-distance commuter trips are currently being made on Amtrak, the forecasted growth in these trips will be limited despite the huge auto market.

1.4 Induced Demand Model

Induced demand refers to changes in travel demand related to improvements in a transportation system, as opposed to changes in socioeconomic factors that contribute to growth in demand. The quality or utility of the transportation system is measured in terms of total travel time, travel cost, and worth of travel by all modes for a given trip purpose. The induced demand model used the increased utility resulting from system changes to estimate the amount of new (latent) demand that will result from the implementation of the new system adjustments. The model works simultaneously with the mode split model coefficients to determine the magnitude of the modal induced demand based on the total utility changes in the system.