Forecasting High-Speed Rail Ridership

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Advantages and disadvantages of various high-speed rail (HSR) ridership forecasting approaches are summarized, and a recommended forecasting approach is presented. The recommended approach involves the use of separate relationships to estimate the diversion from each existing mode to HSR. This approach makes use of the behavioral information travelers have already provided by their revealed preferences to use existing modes for intercity trips. The choice of current modes for specific trip purposes reveals a great deal about how individuals value the attributes of that mode relative to other modes. This information is also of use in estimating induced demand. The approach presented here has been used in forecasting HSR ridership and revenue in Florida, Texas, and the Northeast Corridor. To illustrate how different factors influence the demand for HSR, model results are presented along with implied values of time and selected demand elasticities. The variation between market segments for the various components of travel time and cost is strong evidence that this approach is necessary for forecasting HSR ridership. The resulting models are also shown to be transparent in providing design information for new mode applications that can be used to maximize ridership, revenue, or the public benefits that justify public subsidies for the new modes.

A particular approach that has been used to forecast ridership for proposed high-speed rail (HSR) lines between a number of cities in the United States is described in this paper. (The use of the term "rail" here does not preclude maglev systems, which technically do not operate on rail tracks but otherwise share certain common characteristics with HSR systems.) A review of the procedures used most recently to make projections of HSR ridership in the United States reveals a wide variety of approaches. In the first section of this paper, these approaches and their strengths and weaknesses are reviewed to derive a recommended approach for forecasting HSR ridership.

ALTERNATIVE APPROACHES FOR FORECASTING HSR RIDERSHIP

Description

Although details may differ, three basic approaches have been used recently to forecast ridership for HSR systems. The first approach involves projecting total origin/destination (O/D) travel for the forecast year(s) and using a multinomial mode choice model to determine the share, and thus the number, of trips that would be made by each existing mode and by the new HSR mode. The share of trips by all modes would sum to 100 percent. Typically, a multinomial logit functional form is used for this mode choice step. However, because of the independence from irrelevant alternatives (IIA) property of the logit (or any multimodal share) model, individuals traveling on the new mode are automatically forecast to be drawn from other modes in direct proportion to the share of trips made on the existing modes.

The second approach begins in the same manner as the first, with forecasts of total O/D travel by all modes. To minimize potential IIA problems, a nested choice modeling (e.g., logit) procedure is used to separate automobile trips from common carrier trips. A subsequent choice model is used to separate common carrier trips into those made by air versus HSR. Sometimes the bus mode is also included in this latter choice set. However, in most intercity corridors, bus trips are small in number, and individuals who use buses are much more sensitive to price than to time. Therefore, these trips can usually be ignored in the final analysis of HSR demand.

In both of these approaches, HSR is sometimes treated as a new mode, whereas in other instances, HSR trips are estimated by assuming that the existing rail mode will simply go faster (along with accompanying changes in fares or frequencies or both).

The third approach to forecasting HSR ridership involves projecting trips that would be made by each existing mode, and then determining with separate mode choice models, the share of trips by each mode that could be expected to shift to the new HSR mode as a function of relative service characteristics and other factors found to be important. Just as it is commonly accepted that individual behavior varies by trip purpose (e.g., business versus nonbusiness), this approach recognizes explicitly that individuals traveling on different existing modes exhibit different behaviors when confronted with the choice or opportunity to use HSR. This is because individuals traveling on existing modes have widely divergent values of time and demand elasticities and place different values on the convenience and flexibility attributes of travel by automobile versus common carrier modes.

Assessment

Perhaps the most significant disadvantage of the first approach is the IIA property of multinomial mode choice models mentioned previously. Unless otherwise ameliorated (through use of the second or third approach, for example), the IIA property of models of this type will indicate that the share of riders diverted to HSR will come from other modes in direct proportion to the share of trips made on these other modes. For example, if 80 percent of the trips between any two O/D zones

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are made by auto, then the first approach will indicate that approximately 80 percent of the HSR trips made will be diverted from auto. Analysis of survey results in Florida and Texas indicate that this is not likely to be true (*1,2*).

The main problem with the second approach is determining how the level-of-service characteristics of the existing air and proposed HSR modes (i.e., the high-speed common carrier modes) should be combined for use in the choice model that interacts with auto. This same situation also occurs in the analysis of urban travel demand. Theoretically, it should be dealt with through the use of inclusive prices (or log-sum terms). However, even this approach has certain problems, which are outlined later. In some cases, a rather simplistic all-or-nothing approach is assumed.

In the all-or-nothing approach [used, for example, in the forecasts of HSR ridership for the Texas TGV (*3*)], forecasts of the diversion of trips from automobile to HSR do not incorporate both HSR and air into the level of service for the high-speed mode. Instead, this method assumes first that only air exists, and second that only HSR exists. The highest share is used in each instance. Therefore, if HSR is just slightly less attractive than air, this approach would indicate that zero HSR trips are diverted from auto. All else being equal, this approach is likely to underestimate HSR ridership.

The problem with the use of log-sum or inclusive price terms is that the nesting coefficient on these terms does not change the basic relationship (or set of trade-offs) between the values of the various components of travel time and cost that determine (or derive from) individual preferences for different modes. Because individuals who choose to travel by auto, air, bus, or conventional rail trade off the times, costs, and convenience of those modes differently, separate relationships (models) must be used to forecast the diversion of travel from each existing mode to the new high-speed mode.

The third approach, which is recommended here, recognizes that existing travelers have already revealed, or exhibited, their preferences for the available modes by the choices they have made. Thus, it is necessary only to determine, for each mode and trip purpose market segment, what percentage of travelers will divert to HSR for the service levels assumed. (As indicated later, induced demand is treated separately.) With this approach it is possible to examine functional forms and variable specifications that differ for each market segment. This is not the case for the first two approaches.

RECOMMENDED FORECASTING APPROACH FOR HSR RIDERSHIP

The recommended approach for forecasting HSR ridership (Approach 3) can be described as a three-step process:

1. Estimate demand for travel between O/D pairs by each of the existing modes (and market segment/trip purpose);
2. Quantify the diversion from each existing mode to HSR (by market segment); and
3. Compute the amount of induced travel on the HSR mode.

In summary, the total travel market is broken down into a number of mutually exclusive and readily definable mode and trip-purpose market segments that exhibit distinct patterns of travel behavior. Overall ridership forecasts are prepared by summing across market segments. This approach avoids the forecasting of completely arbitrary diversions of travel from existing modes that do not account for the great variation in the substitutability of the new mode for the various current modes. It also allows for differences in the trade-offs among time, cost, and comfort that characterize travel behavior in different market segments.

Each of the three steps is described in more detail in the following section.

Step 1

In the first step, the total volume of trips by each of the existing modes for a particular time period can be estimated using a direct demand model with the following functional form:

$$T^{m}_{\mathrm{OD}} = f(P_{\mathrm{OD}}, I_{\mathrm{OD}}, LOS_{\mathrm{OD}}) \quad (1)$$

where

T^{m}_{OD} = number of trips by mode m made between O and D,
P_{OD} = population levels in O and D,
I_{OD} = income of travelers between O and D, and
LOS_{OD} = level of service on existing modes between O and D.

Given total demand models of the type shown in Equation 1, projections are made of the number of trips on existing modes in future years (i.e., in the absence of HSR) given projected changes in various input variables (such as the population, income, and level-of-service terms shown in Equation 1).

Step 2

The share of total trips (by trip purpose) made by each existing mode that can be expected to divert to HSR can be estimated using the following functional relationship (a separate relationship is estimated for each existing mode and purpose market segment):

$$S^{m,\mathrm{HSR}}_{\mathrm{OD}} = f(Time^{m,\mathrm{HSR}}_{\mathrm{OD}}, Cost^{m,\mathrm{HSR}}_{\mathrm{OD}}, Frequency^{m,\mathrm{HSR}}_{\mathrm{OD}}, Constant^{m,\mathrm{HSR}}) \quad (2)$$

where

$S^{m,\mathrm{HSR}}_{\mathrm{OD}}$ = share of existing mode m trips between O and D that will divert to HSR;
$Time^{m,\mathrm{HSR}}_{\mathrm{OD}}$ = components of access, egress, and line-haul travel time for mode m and HSR;
$Cost^{m,\mathrm{HSR}}_{\mathrm{OD}}$ = components of access, egress, and line-haul travel cost for mode m and HSR;
$Frequency^{m,\mathrm{HSR}}_{\mathrm{OD}}$ = measures of the frequency and terminal processing times for mode m and HSR; and
$Constant^{m,\mathrm{HSR}}$ = effect of the unobserved characteristics of HSR relative to mode m.

As discussed previously, this approach makes use of the critical finding that people who travel by air, rail, and automobile exhibit different behavior when confronted with the choice or opportunity to use HSR. This means that current and future air, auto, and rail users will divert to HSR in different proportions when offered the same HSR option.

For example, people who choose to drive 4 or 5 hr between cities that are 200 to 250 mi apart can be expected to place a lower value on line-haul time than those who take a 1-hr flight to cover the same distance. Conversely, it is expected that automobile users place a high value on the privacy and convenience of their car, which allows them complete departure time flexibility, control over the rest of their travel schedule (such as making stops along the way), and the ability to take children and extra luggage at no additional cost.

Travelers who have already revealed, or exhibited, these different values will therefore respond quite differently to the travel time, fare, and comfort levels offered by HSR service relative to the mode they currently use. Disaggregating the market in this manner yields results that represent how individuals actually behave in making intercity travel decisions. Of course, the actual diversion to HSR from air, rail, and automobile in any corridor will depend on the actual speeds, fares, frequencies, station locations, and amenities of the new rail service.

Estimating the share of trips by HSR for each market segment using Equation 2 allows an empirical examination of a wide range of explanatory variables. For example, separate line-haul time, access and egress time, wait time, and travel cost variables can be specified. Alternatively, various combinations or transformations of these (or other) terms can be identified. In modeling urban travel behavior, a typical observation is that out-of-vehicle time has about twice the effect of in-vehicle time. When modeling intercity travel behavior, however, this relationship is likely to vary—at least by trip purpose (given different travel party sizes) and trip distance. For instance, when the length of a trip is relatively short, access and egress travel times (or more generally, impedances) may be significantly more important than line-haul time. Conversely, for relatively long trips, the value of access and egress times (as a percentage of line-haul times) is reduced. This result has been noted in two recent major studies (*1,2*).

Because HSR does not yet exist in the United States, it is not possible to use revealed preference techniques to determine how travelers actually trade off characteristics between existing modes and HSR. Solving this problem involves the use of stated-preference survey techniques to measure traveler perceptions and preferences for new modes. The first application of this approach using ordered logit models was the estimation of the demand for electric vehicles (*4*). Subsequently the approach has been used to examine a wide range of issues, from rail station choice (*5*), to telecommunications (*6*), to transit capital improvements (*7*). In the present instance, surveys administered to individuals making relevant trips by current modes can be used to obtain stated preference information on how travelers make trade-offs among different components of time, cost, and technology. This approach has been used to develop models (as illustrated by Equation 2) and estimates of HSR use in Florida, Texas, and elsewhere (*1,2*).

Step 3

Induced travel is estimated in the third step by incorporating the mode choice model utility functions into Equation 1. (Induced travel demand can be defined as trips not currently being made either on other existing modes or to alternative destinations. Induced travel does not include future new trips made because of normal population or employment growth.) In practice, induced travel for a new mode should be closely tied to its market share or its attractiveness relative to existing modes. A new mode that captures 30 to 40 percent of an existing market will probably induce its own trips. If, alternatively, it attracts only 1 percent of existing trips, it is unlikely that much induced travel can be expected.

Because of the relationship between induced travel and modal choice, the methodology for forecasting induced travel must be consistent with the models for forecasting mode choice. This means that the values travelers place on the level-of-service variables from the mode choice models are incorporated into the total demand models (Equation 1). This is done using the mode choice model coefficients that equate the level-of-service improvements on the new mode to the effects on total travel of service improvements on the existing modes. Using this approach will guarantee that the induced travel calculations consistently reflect intermodal trade-offs among service measures across all the travel choices (e.g., trip frequency and mode choice).

Thus, to forecast the induced travel associated with the introduction of the new HSR mode, it is necessary only to calculate how much of a reduction in the equivalent price of travel results from that introduction. The introduction of a new mode that captures a large share of the market will result in a large improvement in the ease of travel. Introduction of a small share mode, in contrast, may have little effect.

MODELING RESULTS

The coefficients and *t*-statistics for various mode choice models that were estimated using data from Texas are presented in Table 1. All the coefficients are statistically significant, except the HSR constant in the air business model. This means that the HSR constant in the air business model cannot be shown statistically to be significantly different from zero (the value of the air mode constant). A value of exactly zero for

TABLE 1 ESTIMATED MODE CHOICE MODEL COEFFICIENTS BY MARKET SEGMENT (FOR INTERCITY TRAVEL IN TEXAS) (*2*)

	Market Segment			
	Air		Automobile	
Variable	Business	Nonbusiness	Business	Nonbusiness
Cost	−0.0379	−0.0609	−0.0283	−0.0321
(1990$)	(−4.5)	(−4.2)	(−2.2)	(−3.3)
Time (composite)	−1.3444	−1.7230	−0.5636	−0.2817
(hours)	(−6.4)	(−5.3)	(−3.4)	(−2.5)
HRS Constant	−0.0599	−0.3325	−0.7710	−1.1967
	(−0.4)	(1.7)	(−1.2)	(−2.3)

NOTE: (*t*-statistics in parentheses).

the mode-specific constant would imply that, if all times and costs of the two modes were equal, air business travelers would be indifferent between air and HSR (i.e., 50 percent would choose one mode, and 50 percent would choose the other). A negative (positive) value of the HSR constant implies that, all else being equal, the share of current travelers who would prefer HSR is less (more) than 50 percent.

Cost and travel time coefficients of all the models presented in Table 1 are negative, implying that increases in travel time or cost of a mode will reduce use of that mode.

Based on the mode diversion models estimated (Table 1) for a proposed HSR system in Texas, it is possible to compute how intercity air and automobile travelers value line-haul time. Table 2 illustrates how the value of time for individuals traveling between Houston and Dallas varies by trip purpose and current mode. As expected, the values of time for air travelers are much higher than for automobile travelers. Also, as expected, the values of time for nonbusiness travelers are lower than for business travelers currently traveling on a given mode. In studies of urban fixed-route and schedule (common carrier) transit travel competing with automobiles, the value of time for access and wait time is commonly observed to be much greater than the value of time for line-haul transit. However, this result is not transferable to the intercity air models because there are two competing common carriers modes, plus a scale difference in the length of the intercity trip. In addition, current travelers are willing to pay dearly for the high line-haul speed of air travel (or they are willing to have their companies pay dearly for business travel, considering the value of their own time to the company and its clients).

In the case of intercity automobile travel, models based on data from Florida indicate that as trip distance (and hence line-haul time) increases, both business and nonbusiness travelers place less importance on access and wait time, and more importance on line-haul time (*1*). As trip lengths increased to nearly 200 mi, the values of HSR line-haul time became greater than the values of access, egress, and wait time. (Houston and Dallas are about 240 mi apart.)

Described in the following sections are the ways in which the values of time, direct elasticities, and modal constants vary by four main market segments: air business, air nonbusiness, automobile business, and automobile nonbusiness travelers.

Business Travel by Air

As expected, air business travelers are very sensitive to line-haul travel time. The value of time for business air trips is about $35 an hr. This figure is equal to 1.3 times the average hourly wage rate of the intercity travelers surveyed in Texas, a result that falls squarely in the range reported in a recent FAA comprehensive literature review of air travel demand models (*8*). The FAA range of 1.0 to 1.5 times the average wage rate is based on 17 models of air business travel demand.

The value of access and egress time for air business travelers presented in Table 2 is $24/hr. This value also reflects the premium this segment places on time. Adjusted for inflation, this value is similar to the mid-1980s value of $17/hr reported by FAA, based on airport access data from San Francisco. It is slightly higher than the 1989 value of $16/hr for this market segment in Florida, but reported traveler incomes in this segment are also higher in Texas than in Florida.

In logit mode choice models such as this, direct elasticities are not constant. Instead, they vary with both the values of the independent variables and the resulting mode share. Consequently, they depend on the assumed fare and service characteristics and the O/D pair. For example, as shown in Table 3, the air business HSR line-haul time elasticity for travel between the areas served by the proposed downtown Houston and downtown Dallas stations at two-thirds of air fare is about −0.86, whereas the HSR fare elasticity is −0.81. The latter falls within the range of −0.8 to −1.2 reported by others (*9*). This −0.81 value was found to increase to above −1.0 as HSR fares are set equal to air fares, indicating that the HSR revenue-maximizing fare is less than the air fare for the proposed HSR service in this corridor.

Finally, the HSR access and egress time elasticity for air business travelers was −0.36. This is a much lower value than for the air business line-haul time elasticity of −0.86, indicating the reduced relative importance of access and egress time for common carrier modes at the 240 mi distance between Houston and Dallas.

TABLE 2 IMPLIED VALUES OF TRAVEL TIME BY MODE AND TRIP PURPOSE IN TEXAS (*2*)

	Trip Purpose			
	Business		Nonbusiness	
Current Mode	Line-Haul Time	Access/Egress Time	Line-Haul Time	Access/Egress Time
Air				
Value of Time (Fraction of Hourly Wage Rate)	$35 (1.3)	$24 (0.9)	$28 (1.5)	$19 (1.0)
Automobile				
Value of Time (Fraction of Hourly Wage Rate)	$20 (1.0)	$13 (0.7)	$9 (0.5)	$6 (0.3)

NOTE: Dollar values are per hour in 1990 dollars.

TABLE 3 HIGH SPEED RAIL ELASTICITIES BY MODE AND TRIP PURPOSE IN TEXAS (*2*)

	Level-of-Service Component		
Mode and Trip Purpose	Line-Haul Time	Access/Egress Time	Fare
Air			
Business	−0.86	−0.36	−0.81
Nonbusiness	−0.85	−0.37	−0.74
Automobile			
Business	−0.61	−0.21	−1.02
Nonbusiness	−0.38	−0.14	−1.05

NOTE: Elasticities calculated for characteristics between Houston and Dallas assuming that high speed rail fares are two-thirds the air fare.

TABLE 4 IMPLIED VALUE OF HSR CONSTANTS BY MARKET SEGMENT IN TEXAS (*2*)

	Trip Purpose	
Current Mode	Business	Nonbusiness
Air	$1.58	($5.46)
Automobile	$27.24	$37.28

NOTE: Values are in 1990 dollars and are equivalent to the fare advantage of existing mode over HSR, keeping all times and costs equal for competing modes.

The implied values of the HSR constants presented in Table 4 strongly support the findings that air and HSR are quite similar in the net effect of the unobserved (or unmeasured) attributes of each mode on ridership. That is, controlling for all the conventional level-of-service attributes included in the mode choice model (cost, line-haul time, access and egress time, and wait time), travelers perceive the air and HSR fixed route and schedule common carrier modes as essentially equal. Automobile travel, on the other hand, is valued quite highly relative to HSR if all the travel times and costs are held equal. Of course, the travel times of HSR and automobile are not equal between Dallas and Houston. Nevertheless, the HSR constants in the automobile mode choice models mean that certain attributes of automobile are valued highly relative to HSR (and presumable to air, although that was not measured explicitly in these models).

The implied value of the HSR constant indicates that if the cost and travel times of air and HSR are equal, business travelers will have a slight preference for air. A HSR fare reduction of less than $2 (or about 3 min reduction in HSR line-haul travel time) is needed to make this group of travelers feel indifferent between the two modes. As noted earlier, however, this is the only coefficient in all the individual market segment models that was not statistically significant. This confirms the hypothesis that business travelers regard air travel and HSR as similar competing common carrier modes.

Nonbusiness Travel by Air

As expected, individuals traveling by air for nonbusiness purposes are less sensitive than business travelers to line-haul time relative to cost. Their implied value of line-haul time is estimated at $28/hr in the Texas corridor (Table 1). This is slightly less than 1.5 times the average wage rate of travelers observed in the survey of air travelers, and within the range reported in the FAA study previously mentioned (*9*). The line-haul time elasticity is about the same for nonbusiness air travelers as for business air travelers (Table 3). Because a high proportion of nonbusiness travelers pay for their own air trip, they clearly value the time savings of the high-speed mode very highly.

The value of the HSR fare elasticity for a HSR fare equal to two-thirds of the nonbusiness air fare is -0.74. This is slightly less than the previously reported range of -0.8 to -1.2 and indicates that at two-thirds of the already lower nonbusiness air fare, the HSR fare is too low in this (proposed) private air and HSR competitive marketplace. The HSR fare elasticity was found to increase to -1.0, its farebox revenue maximizing value, at a HSR fare of about 90 percent of air fare for this market segment and O/D pair.

The value of access and egress time for air nonbusiness trips is about $19/hr (Table 2). This is higher than the mid-1980s value of $10/hr reported by FAA for nonbusiness airport access travel to San Francisco's airport, and by a study of Las Vegas nonbusiness airport access travel. However, the higher values of access and wait times for this market segment relative to Las Vegas reflect the higher incomes of these air travelers relative to the nonbusiness air travelers included in the Las Vegas survey.

The HSR constant is statistically significant, and its implied magnitude (equivalent to $5.46) suggests that, all else being equal, nonbusiness air travelers are somewhat more likely to use HSR than air business travelers. The constant represents how much lower than HSR the air fare would have to be to make travelers indifferent between air and HSR if all travel times were equal. Similarly, if fares were equal, HSR would enjoy a greater than 10-min inherent time advantage over air for nonbusiness travelers.

The difference in the HSR modal constants (relative to air) between business and nonbusiness travelers is reasonable, given the potentially greater comfort of HSR (such as bigger seats, more leg room, and the ability to look out the window and walk between cars). These additional comfort characteristics are likely to be more highly valued by nonbusiness travelers than by business travelers. In the future, it is possible that both types of travelers will value these attributes more highly than when they are actually provided and marketed in revenue service.

Business Travel by Automobile

Travel time is a less important determining factor for individuals traveling on business by automobile than by air. As discussed earlier, individuals who fly would be expected to place a high value on their travel time, whereas individuals who use automobiles place lower values on time but much higher values on the other attributes of automobile travel—flexibility, privacy, and the ability to make multiple stops, for instance. The value of line-haul time for the relatively high-income automobile travelers making business trips between Houston and Dallas is $20/hr (Table 2). This equals the average wage rate of the intercity travelers in this market segment. There are no comprehensive studies of the value of intercity automobile business travel time in the literature. However, this value falls logically between the values of time supported in the literature for both air travelers (referred to previously) and automobile nonbusiness travelers (discussed next). The value of access and egress time for automobile business travelers is again less than the value of line-haul time for this market segment for the 240 mi trip in this corridor.

Note that the values of time (in Table 2) and the demand elasticities for HSR time (in Table 3) are consistent across market segments and modes. That is, because automobile time is not as valuable as air travel time, the demand elasticities are lower for automobile than for air. An hour of saved line-haul time on HSR does not divert as many travelers from automobiles as from air.

Conversely, HSR fare elasticities for automobile travelers are higher than for air travelers. As expected, automobile travelers value saving money more highly than saving time relative to air travelers. Note that at the two-thirds air fare for which these fare elasticities are calculated, both business and nonbusiness automobile travelers turn fare-elastic (that is, lost revenue from lost riders due to a fare increase is greater than added revenue gained from the remaining riders).

The HSR constant in the automobile business model is worth $27.24 of fare reduction to make a traveler indifferent between automobile and HSR if all times and costs explicitly included in the model are equal. Thus, intercity travelers who already have selected a common carrier mode (for example, air) over travel by automobile are much more likely to switch to another common carrier mode, such as HSR, all else being equal. All things considered, automobile business travelers are much less likely to switch to HSR than are air business travelers.

Nonbusiness Travel by Automobile

The value of line-haul time for automobile nonbusiness trips was found to be the lowest among all four market segments, reflecting (again) the discretionary nature of nonbusiness trips relative to business trips (Table 2). The value of $9/hr equals about one-half of the average wage rate of automobile nonbusiness travelers between Houston and Dallas. It is consistent with a large English value-of-time study (*10*), which reported about $6/hr for nonbusiness long-distance automobile trips by the highest income group surveyed (but lower than the income of automobile nonbusiness travelers in the Texas market segment discussed here). The English study did not report actual trip lengths, but a review of the survey methodology suggests that fairly short trips (100 mi) constituted most of the sample.

Again, the value of access and egress time is less than line-haul time for the reasons discussed previously. Indeed, in the intercity Florida corridors (*1*), where trip lengths varied greatly, automobile nonbusiness access times were valued higher than for any other market segment for short intercity trips (85 mi). This result is to be expected because these travelers, who often have children and extra luggage, do not want to divert from automobile travel for short trips on a common carrier mode that involves additional access and egress times.

The elasticities for automobile nonbusiness travelers presented in Table 3 exhibit a similar pattern to that for business travelers who travel by automobile. The lower values of time result in lower time elasticities and higher HSR fare elasticities. The HSR fare elasticity would be even higher than that shown in Table 3 if the nonbusiness air fare were not already one-third lower than the business air fare.

The automobile nonbusiness market segment has the largest negative mode-specific HSR constant (equivalent to $37.28) among the four travel market segments reported here. This result is to be expected because nonbusiness travelers (e.g., individuals on vacation) most need the features of an automobile. Therefore, if times and costs are held equal, this group of intercity travelers is the least likely to switch to HSR.

Forecasting Model Applications

Most travel on HSR systems will be diverted from existing modes in the high-volume intercity markets where they are being proposed. These corridors are already served by Interstate highways, frequent air service, and (sometimes) conventional rail service. The modeling results described here provide important information for designing HSR applications that maximize ridership and passenger fare revenue. For example, the modeling results show that the passenger revenue maximizing fares that may be charged for HSR are very sensitive to whether the new mode's utility function (i.e., weighted travel time) is less or more than air. A shorter corridor (200 mi instead of 300 mi) will allow exploitation of the ability of HSR to offer multiple on-line stations in the areas served, reducing access and egress time without increasing waiting time. Air travel does not offer this feature, but the trade-off is extra line-haul travel time for the ground mode that may only be affordable for the shorter, 200-mi intercity travel distances.

Integrating HSR stations into local and regional transportation systems is therefore extremely important. Local access is a key variable in forecasting HSR ridership. Many private and public benefits can be obtained from facilitating access to and from the HSR system. If these private benefits are captured through the farebox, passenger revenue on HSR can be maximized. Conversely, HSR may be priced to maximize ridership and the benefits it provides from the reduced air and highway congestion, energy consumption, and air pollution that justify the public capital subsidies that most likely will be needed to build and operate HSR. The trade-offs between the private benefits of HSR captured through the farebox and the public benefits from foregoing farebox revenue are important outputs from using these models. They provide improved market understandings for system design and evaluation purposes.

The models presented in this paper therefore facilitate an understanding of how travelers on existing intercity modes value the potential travel-time savings offered by HSR and what the effects on demand and revenue are of the possible access and egress and waiting and terminal processing time advantages of the new modes.

CONCLUSION

The following three-step approach for forecasting HSR ridership is recommended.

1. Total air, automobile, and conventional rail volumes are each modeled separately using revealed preference (behavioral) data.
2. Separate air, automobile, and conventional rail (where relevant) mode choice models are estimated using stated preference methods. These models are applied to forecast the diversion of trips from each existing mode to HSR by trip purpose.
3. Induced travel is forecast on the basis of the behavioral relationships in the first two models.

A great advantage in forecasting ridership is that most travel on HSR will be diverted from existing modes in the corridors in which it is being seriously considered. It allows use of the behavioral information travelers have already provided by their revealed preferences to use these modes for their intercity travel. A critical finding is that persons who travel by air, automobile, and conventional rail exhibit different behavior when confronted with the choice or opportunity to use a new high-speed mode.

The resulting models have attractive properties in their ability to forecast the different rates of travel substitution between HSR and the existing modes and to incorporate the different values of time and other (nonquantifiable) factors that determine the mode choice of current intercity travelers. The models are also quite transparent in the way they reveal market driven information for HSR design and evaluation purposes. Finally, the Texas and Florida values of time and demand elasticities presented in this paper show that the modeling results have considerable face validity and conform well to the results of earlier studies.

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