Patronage Forecast for the Proposed High Speed Passenger Rail Service between Tulsa and Oklahoma City

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Anticipated patronage is a principal consideration in high speed rail passenger (HSR) service investment studies. Because of its importance, the state-of-the-practice requires collection of primary data on travel patterns and volumes in the corridor where HSR service is planned. The surveys necessary to conduct investment grade patronage forecasts require substantial resources and time which may not be available at the earliest stages of planning. Data collection is typically among the most expensive tasks in planning and forecasting use of passenger rail systems. Before committing the resources necessary to develop sufficiently detailed and reliable patronage forecasts for making build/no build decisions, decision-makers use lesser quality threshold forecasts to judge the merits of proceeding with more detailed studies of project potential. Refinements to these forecasts occur as projects advance through planning and design.

The proposed HSR service between Oklahoma City and Tulsa is a segment on a spoke of the Congressionally designated South Central Corridor high speed passenger rail network centered on the Dallas-Ft. Worth area (see Figure 1). When viewed as part of a system, passenger traffic between Oklahoma City and Tulsa will consist of travelers with many different origins and destination including Tulsa to San Antonio and, eventually, Oklahoma City to Chicago. The viability of the Oklahoma City to Tulsa line rests on the synergies resulting from connecting to a larger network and not just on the passenger volumes between the two cities.

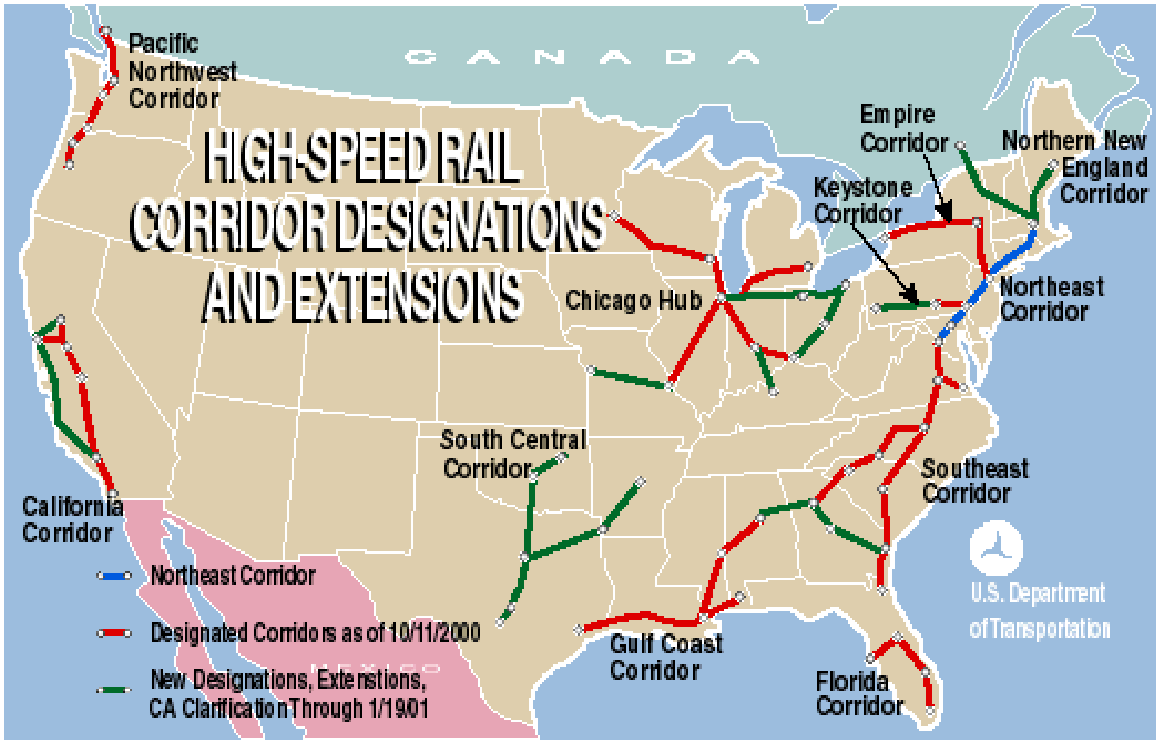
Typically, patronage forecasts are prepared for each origin-destination pair separately. Tulsa and Oklahoma City constitute two significant population centers in the South Central Corridor. There should be passenger traffic between the cities which might be in the market for high speed rail service depending on a variety of factors only some of which can be quantified. Terminal location and accessibility are both critical to attracting patrons. So are adequate and secure long term parking, supportive land use policies, and good local public transit with service to the terminals. These factors help define the extent of the market area.

The proposed HSR service between Oklahoma City and Tulsa is in an early stage of planning. In deciding whether to continue studies of the project, decision-makers risk two types of errors: (a) not proceeding when the project is actually justified; and (b) proceeding when the project is not justified. Of the two types of error, in the early stages (a) may have the highest opportunity cost if the benefits of a viable project are forgone. To reduce the chance of this type of error for the Oklahoma City to Tulsa HSR line, the goal of the patronage forecasts should be to establish an upper limit on ridership, that is, the maximum likely volume of passengers within the planning horizon. We consistently make assumptions throughout this analysis favorable to HSR ridership to minimize the chance of committing a type (a) error.

Figure 2 shows the Tulsa to Oklahoma City corridor. The HSR terminals are in the central business districts of both cities. No intermediate stops were assumed in this analysis although park and ride lot alternatives as well as alternative terminal locations such as at the airports are still under consideration. The alignment we analyzed parallels the Turner Turnpike (Interstate Route 44) for most of the trip, following existing rail rights-of-way within the cities themselves.

We forecast Oklahoma City to Tulsa HSR patronage using three different methods all of which rely in part on data collected in other HSR studies. The first approach estimates Oklahoma City to Tulsa HSR patronage using a mathematical relationship derived from primary data collected in connection with HSR studies in other parts of the U.S. A second approach applies a patronage forecasting model developed for a proposed HSR service between Tampa and Orlando, Florida, to the Oklahoma City to Tulsa corridor. The third approach is to scale the proposed Oklahoma City to Tulsa HSR patronage to service planned in a comparable corridor, again the Tampa to Orlando, Florida, corridor, where forecasts based on primary data are available. This report documents all three approaches and uses the highest patronage forecast obtained to establish an upper limit on patronage. The planning horizon is the year 2010.

FIGURE 1 Designated national high speed rail corridors



SOURCE: Federal Railroad Administration (http://www.fra.dot.gov/rdv/hsgt/states/index.htm).

FIGURE 2 Proposed high speed passenger rail alignment between Tulsa and Oklahoma City

[SEE SEPARATE PAGE FOR THIS FIGURE]

SOURCE: Oklahoma Department of Transportation

METHOD 1: REGRESSION MODEL

The first method attempts to fit the proposed Oklahoma City to Tulsa HSR line into a range of patronage forecasts obtained from other HSR markets currently under study. The eight markets shown in Table 1 have recently completed patronage forecasts which provide a range from relatively small (Tampa to Orlando) to very large (San Francisco to Los Angeles). Figure 3 plots daily patronage and the termini population for these eight markets. For comparison purposes, the proposed Oklahoma City to Tulsa HSR line is shown with forecasted patronage equal to 1600 daily rider.

TABLE 1 Area and service characteristics and patronage forecasts for seven proposed U.S. high speed passenger rail projects

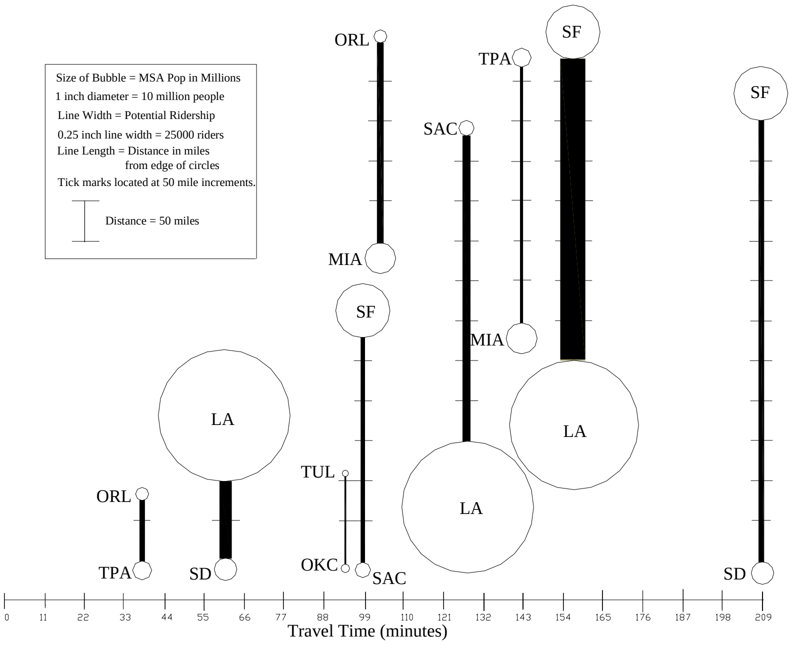
Termini	Population of termini (000,000s)[a]	Travel time (minutes)	Distance b/t termini (miles)	Trains per day	Patronage per day[b]
Tampa (TPA) to Miami (MIA)[c]	4.649	145	319	24	3014
Sacramento (SAC) to San Francisco (SF)	8.836	100	282	22	4658
Tampa to Orlando (ORL)	2.627[d]	37	73	14	1241 - 1595
San Diego (SD) to San Francisco (SF)	9.853	209	553	32	6301
Orlando to Miami	3.898	103	246	32	7726
Los Angeles (LA) to Sacramento	18.170	129	380	32	9315
San Diego to Los Angeles	19.187	60	151	32	14,521
Los Angeles to San Francisco	23.412	150	402	32	30,685

NOTES: [a]Population in year 2000. [b]Patronage forecast for the year 2010. [c]Miami metropolitan population only includes the Miami-Ft. Lauderdale PMSA to better reflect the expected market. [d]Includes all the Orlando MSA but only the Hillsborough County portion of the Tampa MSA to better reflect the expected market. See Appendix A for sources of data.

Figure 3 reveals the strong relationship between market population and forecasted patronage. The horizontal axis indicates travel time between city pairs in minutes including intermediate stops. Since some proposed lines have similar travel times, city pairs may appear near the top of the graph to avoid overlaps. Consequently, the chart has no y-axis and no particular interpretation is intended regarding the vertical location of a city pair. Distance between terminals can be determined by counting tick marks; each tick mark equals 50 miles. Line length is measured between outer circle edges. The areas of the circles represent terminal city population. The thickness of the lines connecting terminal cities indicates forecasted ridership taken from recent technical publications. Appendix A explains construction of this figure.

We investigated alternative specifications of linear and non-linear models in an effort to quantify and summarize the relationships in Figure 3. The dependent variable was forecasted daily trips for the linear models and the log of forecasted trips for the non-linear models. Independent variables included population of the termini, terminal to terminal travel time, terminal to terminal travel distance, and train frequency. In most specifications excluding the Los Angeles to San Francisco line improved results but at the cost of a degree of freedom in a small sample. Table 2 reports results for ten representative models. Population of the terminal markets is consistently the strongest explanatory variable regardless of other variables included in the analysis for both linear and non-linear models. Travel time was not significant in any of the models even though the coefficients always had appropriate signs and magnitudes. Train frequency was significant in model #6 which also had the highest coefficient of determination (R^2). The mean absolute percentage errors (MAPEs) ranged from 25% to 51%.

FIGURE 3 Relationship between forecasted patronage and the population of terminals and terminal to terminal travel time



The importance of the constants in the exponential models (numbers 8, 9, and 10) combined with low *t* values for population at the termini (significant at the 90% level but not the 95% level) suggests these models are a poor fit for the data. The constants and the travel time parameters in the linear models are not convincingly significant.

Available patronage forecasts are for lines proposed to serve much larger markets than Oklahoma City and Tulsa. Consequently, constants can dominate forecasts for lines connecting small urban areas. For example, model #1 yields a forecast of more than 1500 daily passengers when market size is zero. Of the models we examined with zero intercepts, model #4, estimated from data which excludes the Los Angles to San Francisco line, is the best predictor and has the most logical structure. The coefficient on the population variable is significant at the 98% level. Model #4 has the lowest MAPE, and an acceptable R^2 value. It yields a year 2010 forecast of 1256 daily passengers between Oklahoma City and Tulsa.

METHOD 2: BORROWED MODEL APPROACH

The second method of patronage forecasting makes use of a class of model known as *discrete choice* which yield estimates of the proportions of travelers choosing competing modes based on the service characteristics of the modes and the characteristics of the travelers. Multiplying these proportions by the number of travelers sharing relevant characteristics produces a forecast of passenger volumes. Inputs into this model include:

1. a disaggregation of the total travel market (i.e. the total number of persons who might choose to take the train) into smaller market segments based on the characteristics of the trips they are making and the characteristics of the travelers;
2. the service characteristics of the competing modes (in- and out-of-vehicle travel time, travel cost); and
3. socioeconomic characteristics of the travelers such as income, auto availability, and household size.

TABLE 2 Fitted statistical models to data in Table 1 (dependent variable is daily patronage)

Model	Constant	Population	Travel Time	Frequency	R^2	MAPE	OKC-Tulsa Forecast
1	1541.9 (0.85)	540.6 (3.43)			0.70	30.2	1039
2*	0	944.8 (9.9)	-5.92 (-0.23)		0.70	41.0	1466
3	3548.1 (1.08)	528.7 (3.19)	-16.1 (-0.71)		0.74	41.2	3617
4	0	653.6 (7.81)			0.66	20.4	1256
5	-3786.96 (-0.98)	377.1 (2.72)		256.9 (1.95)	0.81	35.6	0
6*	-3361.1 (-0.34)	949.4 (3.32)		84.8 (0.25)	0.71	51.2	2249
7	0	423.3 (2.52)		106.8 (1.54)	0.77	34.2	1347
8	3593.1 (22.7)	1.09 (2.91)			0.63	31.4	2804
9	2188.6 (11.67)	1.06 (2.62)	0.997 (0.14)		0.63	30.7	2690
10*	563.6 (11.23)	1.07 (4.17)		1.06 (3.31)	0.90	22.3	878

NOTES: *t* statistics in parentheses. Asterisk (*) indicates the Los Angeles to San Francisco line was included in the model. Models 1 through 7 are linear of the form:

$$patronage \ = \ constant + b_1(population) + b_2(service \ \ variable)$$

Models 9 through 10 are exponential of the form:

$$patronage \ = \ (constant)(b_1^{population})(b_2^{service \ \ variable})$$

Typical applications of discrete choice models involve extensive data collection efforts including personal interviews with travelers. This data is used to *calibrate* models in order that they produce results representative of the population for which the forecasts are being prepared. The budget for the Oklahoma City to Tulsa high speed rail project is not sufficient for the data collection program necessary to develop a model specific to Oklahoma. Such a data collection program will have to be done prior to any build/no build decision.

In the absence of primary data, a form of the discrete choice model called *pivot point* can be used to generate preliminary forecasts. This version of the model applies parameters borrowed from a comparable area to local data. Eq. (1) describes this form of the model.[1]

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[1] Ortúzar, J., and L. Willumsen, *Modelling Transport*, 2nd ed., John Wiley & Sons, 1994, pp. 357-358.

$$\acute{p}_k = \frac{P_k^0 \exp(\acute{V}_k - V_k^0)}{\sum_k P_k^0 \exp(\acute{V}_k - V_k^0)} \qquad \textbf{(1)}$$

where

$\acute{p}_k$ = proportion of trips choosing mode *k* after a service change
p_k^0 = proportion of trips choosing mode *k* before a service change
$\acute{V}_k - V_k^0$ = the change in utility of choosing a mode resulting from a service change

The borrowed parameters are used to estimate the utility of the modes competing in the travel market.

The comparable market

The Florida High Speed Rail Authority, an entity created to oversee establishment of high speed passenger rail service in Florida, recently commissioned "investment grade" ridership forecasts for proposed service in the Orlando to Tampa corridor.[2] This project involved extensive data collection including interviews with potential users of the service.

The study examined two possible model structures, one developed by AECOM Consulting and the other by Wilbur Smith Associates (WSA). As the WSA formulation employs more easily developed inputs, we found it most adaptable to the Oklahoma City to Tulsa corridor. This model disaggregates total intercity travel into five categories:

1. Resident commuters;
2. Resident business;
3. Non-resident business;
4. Resident non-business; and
5. Non-resident non-business.

In addition to the above five submarkets, WSA examined potential patronage to and from Orlando International Airport. As airline service characteristics into Orlando International Airport differ significantly from those into Will Rogers World Airport and Tulsa International Airport, we judge this aspect of the study not applicable in forecasting ridership in the Oklahoma market.

The similarities between the Florida and Oklahoma corridors are sufficient to justify use of the Florida model to aid in setting a probable upper limit on Oklahoma City to Tulsa patronage. Greater precision will require additional data collection in the Oklahoma City to Tulsa corridor. There are at least five major differences between the Florida and Oklahoma corridors which might be expected to influence model coefficients. Population and population density in the Tampa to Orlando corridor are higher than in the Tulsa to Oklahoma City corridor. Table 3 shows population trends for the two markets. Second, intermediate stops at “Orlando attractions” and Lakeland would not exist between Oklahoma City and Tulsa.. Third, tourism in Florida is a much larger market than in Oklahoma and likely represents a larger component of non-business trips than would be the case in Oklahoma. Fourth, the Florida patronage forecasts are based on a service plan with minimum one hour headways operating eighteen hours per day 365 days per year[3] whereas five trips per day are proposed for the Oklahoma City to Tulsa

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[2] AECOM Consulting and Wilbur Smith Associates, *Invesmtment Grade Ridership Study: Summary Report*, 20 NOV 2002.

[3] Lynch, et.al., *Travel time, safety, energy, and air quality impacts of Florida high speed rail*, op.cit., p. 9.

corridor over a 12.5 hour period. Fifth, the Tampa to Orlando line will be part of a triangular system directly linking both cities to Miami, whereas the Oklahoma City to Tulsa line is part of a radial system with a hub in Ft. Worth.[4]

TABLE 3 Population of the Orlando, Tampa, Tulsa and Oklahoma City, census metropolitan areas: 1990 - 2010

	1990	2000	2010
Oklahoma City, OK[a]	958,839	1,082,700	1,113,900
Tulsa, OK[a]	708,954	784,500	838,300
Orlando, FL[b]	1,224,884[c]	1,644,561[c]	1,758,176[d]
Tampa, FL[e]	834,054[c]	998,948[c]	1,100,941[d]

SOURCES: [a]Oklahoma Department of Commerce, State Data Center; [b]Includes Orange, Osceola, and Seminole counties. [c]Florida Demographic Forecasting Conference (http://fred.labormarketinfo.com/); [d]AECOM Consulting and Wilbur Smith Associates, *Investment Grade Ridership Study: Summary Report*, 20 NOV 2002, p. 4. [e]Includes only Hillsborough County to better reflect the market size for high speed passenger rail service.

Table 4 lists the variables and coefficients for WSA's model of travel in the Orlando to Tampa corridor. The coefficients are used to calculate the utilities (V_k) in Eq. (1). "Total travel time" includes both in-vehicle and out-of-vehicle travel time. "Travel cost" refers to out-of-pocket expenses plus vehicle wear-and-tear. Business travel costs were $0.36 per mile; non-business costs were $0.12 per mile. An important exception was access to the passenger rail line from rental cars where lower mileage charges applied ($0.06 per mile). Surveys conducted in connection with the Florida study indicated 57% of all non-resident business travel and 62% of non-resident non-business travel in the Orlando to Tampa corridor used rental cars. These values become important when estimating user benefits.

"Damped frequency" is a term introduced to the model to capture the diminishing effect on patronage of adding trains to the schedule. The term reduces the increase in patronage which would otherwise result from a reduction in access/egress time. As train frequency increases, egress times decline since wait time at destinations is reduced. Without the damped frequency term, the model overestimates the patronage gain resulting from increases in the number of trains offered. Both the AECOM Consulting and WSA models incorporate a damping term for train frequency.

The "rail constant" also decreases patronage. AECOM Consulting describes the rail constant as incorporating "... all of the un-measured differences not reflected in the travel time, cost, and other characteristics that are quantified in the utilities.[5] They justify its use as follows:

> "... the values of these constants are based on the stated preference survey data and thus include any stated respondent biases that may differ from actual future behavior. In other corridor markets, where rail currently exits and it is possible to compare stated and actual observed mode choice, one typically sees a tendency of respondents to over-state their willingness to shift to the new rail mode."[6]

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[4] Some plans foresee connecting the line from Ft. Worth to OKC to Tulsa into the southwestern spoke of the Midwest High Speed Rail Initiative hub in Chicago.

[5] AECOM and Wilbur Smith Associates, *Investment Grade Ridership Study: Supplemental Details*, 20 NOV 2002, pp. C.11-C.12.

[6] ibid.

Note the constant is lower for non-business travel than it is for business travel, indicating non-business travelers are less likely to use the rail mode than business travelers all other factors equal.

TABLE 4 Intercity mode choice model coefficients from the Wilbur Smith Associates study of the proposed Orlando to Tampa, Florida, high speed passenger rail service

Market	Total travel time (min.)	Total travel cost ($)	(Access + Egress time) ÷ distance (min/miles)	Damped frequency [1 - exp(-0.15* freq)]	Rail constant
Resident commuter	-0.00997	-0.00143	-1.59	1.51	-1.961
Resident business	-0.00997	-0.001014	-2.29	1.51	-1.961
Non-resident business	-0.00598	-0.01214	-2.29	1.51	-1.961
Resident non-business	-0.00822	-0.02907	-1.888	2.66	-2.9
Non-resident non-business	-0.00493	-0.02907	-1.888	2.66	-2.9

SOURCE: AECOM Consulting and Wilbur Smith Associates, *Investment Grade Ridership Study: Supplemental Details*, 20 November 2002, p. 8.

The Florida model recognizes that some trips not currently occurring might become practical if high speed passenger rail service were available. This market is called "induced demand." While the existence of induced demand is well known there is considerable controversy about how to forecast these trips. WSA used the simple linear relationship shown in Figure 4 where diverting twenty percent of the total trips between two termini yields induced traffic equal to "... eight percent of the same potential market."[7] For example, if the total market were 1000 trips and rail captured 20% of them, total rail ridership would equal 280 (20% of 1000 plus 8% of 1000). Note further that the definition of induced demand means the total market expands to 1080 trips and 800 travelers choose non-rail modes.

When applied to the Oklahoma City to Tulsa corridor data, this method produced induced trips equal to more than 20% of total ridership, a number we felt exceeded what could reasonably be expected to occur even under optimistic assumptions. More realistic results are obtained by applying the Figure 4 curve to diverted rather than total trips which is the procedure used in this analysis. Theory does not suggest there will be any induced commuter trips.

Modal shares in the Oklahoma City to Tulsa travel market

Eq. (1) is called a pivot point model because future modal shares shift around an existing set of known mode shares, the term p_k^0 in Eq. (1). When applied, the pivot point form of the logit model produces an estimate of the proportion of travelers choosing competing modes when the service characteristics of one or more of the modes changes. As passenger rail service does not currently exist in the Oklahoma City to Tulsa corridor, modal shares from a comparable market must substitute. Within Oklahoma, passenger rail service exists only between Oklahoma City and Ft. Worth, Texas. Table 5 compares the two markets.

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[7] ibid. p. D.8.

FIGURE 4 Relationship between diverted and induced travel

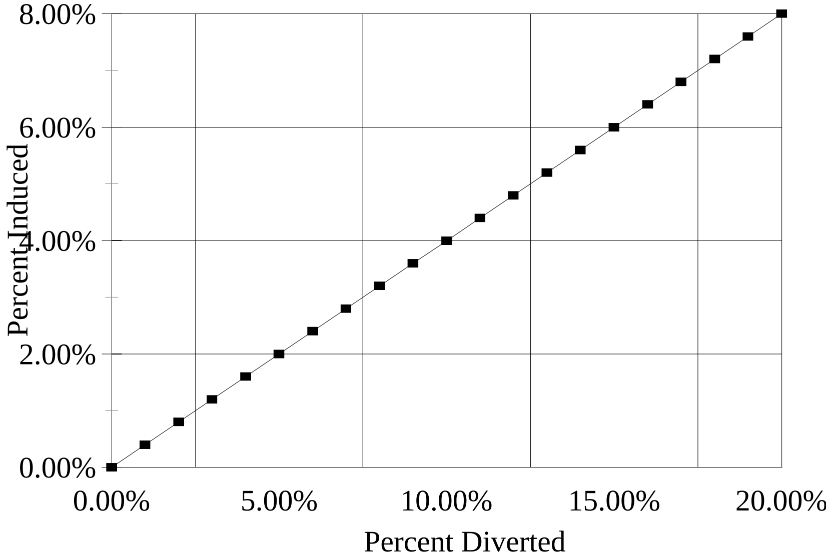

TABLE 5 Oklahoma City to Fort Worth and Oklahoma City to Tulsa travel markets by passenger rail

	Oklahoma City - Ft. Worth	Oklahoma City - Tulsa
Terminal to terminal distance	206 miles[a]	101.68 miles[b]
Population of terminal metro areas	6,305,147[c]	1,886,581[d]
Travel time by auto	225 min.[e]	100.75 min.[f]
Travel time by rail	280 min.[g]	NA

NOTES: [a]AMTRAK, *National Timetable*, National Railroad Passenger Corporation, 29 April 2002, p. 49. Distance scaled from map = 209 miles. [b]Unpublished data, Carter-Burgess Associates, August, 2002. [c]U.S. Bureau of the Census, year 2000, STF-1 file, for the Oklahoma City MSA and Dallas - Ft. Worth CMSA. [d]U.S. Bureau of the Census, year 2000, STF-1 file, for the Oklahoma City and Tulsa MSAs. [e]Approximated assuming freeway speed of 65 MPH, suburban speed of 55 MPH, and urban speed of 20 MPH. Does not include terminal times. [f]Average of four travel time measurements (see Appendix C). Does not include terminal time. [g]AMTRAK, *National Timetable*.

Appendix B lists monthly modal utilization in the Oklahoma City to Ft. Worth travel corridor in the year 2001, the only year for which complete data exists. Amtrak service in this corridor captured approximately 1.12% of the total trips between the two destinations in this year. Since data on modal shares by trip purpose does not exist, our best estimate of mode split proportions for a particular trip purpose is the annual average proportion for all trip purposes, 1.12%, set equal to the term p_k^0 in Eq. (1). Note that use of annual data controls for seasonal fluctuations.

If rail passenger service were operating in the Oklahoma City to Tulsa corridor at an average speed comparable to that observed in the Oklahoma City to Ft. Worth corridor (44 MPH), travel time by rail would be 141 minutes. This and other approximations allow creation of a description of travel in the Oklahoma City to Tulsa corridor before and after introduction of high speed passenger rail service, as shown in Table 6.

TABLE 6 Service characteristics of competing modes in the Oklahoma City to Tulsa corridor

	Before improvement	After improvement
Terminal to terminal travel time (rail)	141 min.	59.4 min.[a]
Terminal to terminal travel time (auto)	100.75 min.	100.75 min.[b]
Access/egress time (rail)[c]	1 hour	1 hour
Access/egress time (auto)[d]	10 minutes	10 minutes
Out-of-pocket trip cost - business (auto)[e]	$42.50	$42.50
Out-of-pocket trip cost - nonbusiness (auto)[e]	$16.50	$16.50
Out-of-pocket trip cost (rail)	$15.25[f]	$28.00[g]

NOTES: [a]Unpublished data, Carter-Burgess Associates, August, 2002. [b]Assumes no increase in congestion on the Turner Turnpike. [c]Assumes travel to local destinations via public transportation within service area of diameter 20 miles. [d]Assumes walking speed of 1.5 MPH. [e]Auto distance equals 108.25 miles. Assumes $0.36 per mile operating cost for business travelers and $0.12 per mile for non-business travelers plus $3.50 toll. [f]Scaled to Oklahoma City to Ft. Worth Heartland Flyer fare, i.e. (108.25/206)$29 = $15.25. [g]Assumes farebox recovery of 100% of operating costs, per mile operating cost of $35.69 per mile (Carter-Burgess Associates correspondence, August 2002), five trains per day, 365 days per year.

The size of the Oklahoma City to Tulsa travel market

Our field research revealed no significant utilization of bus, rail, or air modes in the Oklahoma City to Tulsa travel market; virtually all travel is by auto. The best data on the auto travel market is collected by the Oklahoma Transportation Authority (OTA) which operates the Turner Turnpike (Interstate Route 44) connecting the two cities. The OTA provided unpublished reports on the numbers of two-axle vehicles, their origins and destinations, and toll payment methods, for a sample of months for the period January, 1993, through November, 2002, a total of 36 observations. In its raw form the OTA data omits some OKC-Tulsa travelers and over-counts others. For example, some OKC-Tulsa travelers undoubtedly use the parallel, slower, un-tolled highway to reduce out-of-pocket cost. We omit these travelers from the OKC-Tulsa high speed passenger rail market on the basis of their demonstrated willingness to avoid paying tolls for travel time savings. Additionally, some travelers included in the OTA two-axle vehicle counts have origins and destinations outside the Oklahoma City to Tulsa corridor. A trip from Los Angeles to Chicago would appear as a cash paying two-axle vehicle on the Turner Turnpike traveling between OKC and Tulsa in the OTA data. Since the Turner Turnpike is an signed Interstate Highway, the proportion of "through" traffic is likely high. Our assumption, consistent with the desire to establish an upper limit on HSR patronage, was to consider all non-Oklahoma licensed vehicles as through traffic. Finally, we multiplied the Oklahoma licensed vehicle counts by vehicle occupancy to obtain the number of person trips in the Oklahoma City to Tulsa market. The Orlando to Tampa travel survey revealed average vehicle occupancy by trip type to be: commute = 1.27, business = 1.15, and other = 2.45. Our own field study of Turner Turnpike two-axle vehicles indicated there were 1.39 persons per two axle vehicle for all trip purposes.

Figure 5 shows the generally stable pattern of travel between Oklahoma City and Tulsa over the nine year period covered by the OTA data. Note the seasonal pattern in this data. Combining this sample with published OTA quarterly data provides a means of estimating the number of Turner Turnpike travelers between Oklahoma City and Tulsa for each quarter over the ten year period.

FIGURE 5 Total passenger vehicles traveling between Oklahoma City and Tulsa on the Turner Turnpike and numbers of vehicles paying tolls with a Pikepass for selected months: January, 1993, to November, 2002

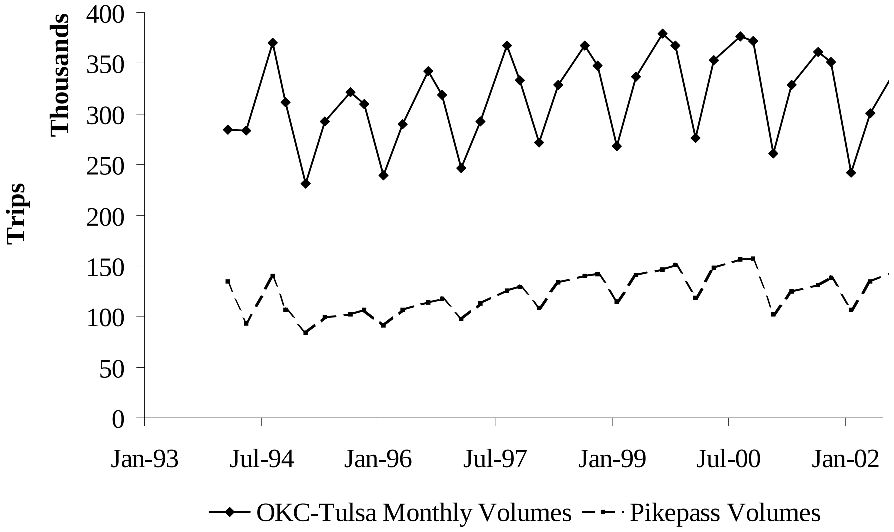

Figure 5 tracks two series. The top series includes all vehicles paying the two-axle toll to travel between Tulsa and Oklahoma City. This series has been stable with evidence of decline beginning with the July, 2000, observation. The second series is a subset of the first and tracks a class of users who pay their tolls electronically with a fare card called “Pikepass.” These travelers constitute one of the most promising markets for high speed passenger rail service since they travel the corridor often enough to make electronic toll payment attractive. This series has grown faster than the larger two-axle population. Consistent with the objective of setting an upper reasonable limit on the patronage forecast, all Pikepass users can be considered members of the market for high speed passenger rail service even though some are undoubtedly "through" trips.

Table 7 shows Turner Turnpike two-axle vehicle use by month and quarter for the year 2001. It also shows the method used to factor the OTA sample of monthly data into annual data for different toll categories and origins and destinations. Table 8 translates these totals into an estimate of the maximum number of vehicle trips from which high speed passenger rail service could attract patrons for travel between Tulsa and Oklahoma City, some 2,123,500 in the year 2001. Note Table 8 employs the "assumption" method in which whole toll payment categories are assigned to the Oklahoma City to Tulsa high speed passenger rail market.

Total vehicle-trips must be converted into person-trips by trip purpose for which primary data on the Oklahoma corridor does not exist. Trips by purpose in the Tampa to Orlando corridor estimated by AECOM Consulting are shown in Table 9. Given the acknowledged differences in the Florida and Oklahoma markets, these percentages cannot be applied in Oklahoma without adjustment. Two trip purposes most likely to be proportionately similar in the two markets are resident and non-resident business trips, although this latter purpose could be somewhat higher in Florida due to its large convention industry. Florida tourism certainly yields more non-resident, non-business trips than the Oklahoma corridor experiences. Similarly, attractions in the Florida corridor most likely generate more resident non-business trips than in Oklahoma.

TABLE 7 Numbers of vehicles paying the two-axle toll on the Turner Turnpike: 2001

	Month (Quarter)			
	January (1st)	April (2nd)	September (3rd)	October (4th)

A	Monthly total (all origins and destinations)[a]	772,161	914,043	989,486	975,297
B	Monthly total (OKC-Tulsa)[a]	260,873	328,431	361,085	351,548
C	Monthly Pikepass (OKC-Tulsa)[a]	102,261	124,640	131,304	138,506
D	Quarterly total (all Os and Ds)[b]	2,450,229	2,881,131	2,878,561	2,879,313
E	Quarterly Total (OKC-Tulsa)[c]	827,805	1,035,239	1,050,450	1,037,855
F	Quarterly Pikepass (OKC-Tulsa)[d]	324,496	392,874	381,983	408,903

NOTES: [a]Oklahoma Transportation Authority, unpublished data, April 2003. [b]Report to Bondholders, quarterly series, 1st quarter, 1994 through fourth quarter, 2002. [c]E = (B/A)*D. [d]F = (C/B)*E.

TABLE 8 Auto vehicle trips which could be diverted to high speed passenger rail service between Oklahoma City and Tulsa: 2001

		Total in OKC-Tulsa Corridor	Total in OKC-Tulsa HSR market
A	Total vehicles (OKC - Tulsa)	3,951,349	
B	Pikepass (OKC - Tulsa)	1,508,256	1,508,256
C	Cash Payers (OKC-Tulsa) (A - B)	2,443,093	
D	Proportion "Out of State"[a]	0.236	
E	Number of "Out of State" vehicles (C X D)	576,570	
F	Number of Oklahoma resident cash payers (C - E)	1,866,523	615,193
	TOTAL		2,123,449

NOTES: [a]Survey by R. Marshment and D. Karapanagiotis at the McDonalds service plaza near the Wellston exit on I-44 westbound, March 5, 2003.

Our approach was to establish an upper limit on total person-trips and then subdivide that total among trip purposes. Our field studies on average vehicle passenger occupancy for two axle vehicles with Oklahoma license plates on the Turner Turnpike is 1.39. Applying this rate to 2,123,449 vehicle-trips in the HSR market yields total person-trips of 2,951,594. Year 2000 census data indicates 1,336 people commuted between the Tulsa and Oklahoma County market areas.[8] Annualizing 1,336 commuters by 260 days per year gives a year 2000 estimated

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[8] Market area defined as Canadian, Cleveland, Oklahoma, Rogers, and Tulsa counties. *Residence County to Workplace County Flows for Oklahoma Sorted by Residence State and County*, U.S. Census Bureau (http://www.census.gov/population/cen2000/commuting/2KRESCO_OK.xls).

commuter market of 373,356. Year 2000 census data also indicates the Oklahoma City and Tulsa metropolitan statistical area populations (1,837,200)[9] were 45.5% of the population of the Tampa to Orlando MSA populations (4,040,558).[10] Applying this percentage to the number of resident business and non-resident business trip totals for the Orlando to Tampa line in Table 9 yields estimated 2000 Oklahoma City to Tulsa person-trip volumes of 1,265,856, and 148,684, respectively. When combined with commute trip this totals 1,787,896. We split the remaining 1,163,698 person-trips equally between the resident non-business and non-resident trip purposes.

TABLE 9 Person-trips by trip purpose in the Tampa to Orlando and Oklahoma City to Tulsa corridors: 2000

Trip Purpose	Tampa to Orlando[a]	Proportion	Vehicle Occupancy Rate[a]	OKC-Tulsa (person-trips)[b]	Proportion	OKC -Tulsa (person-trips)[c]
Commute	1,182	0.0580	1.27	373	0.1265	401
Resident business	2,784	0.1366	1.15	1,266	0.4289	1,361
Resident non-business	9,770	0.4794	2.45	582	0.1971	669
Non-resident business	327	0.0160	1.15	149	0.0504	160
Non-resident non-business	6,316	0.3099	2.45	582	0.1971	669
TOTALS	20,380	0.9999		2,952	1.0000	3,260

NOTES: [a]AECOM Consulting and Wilbur Smith Associates, *Investment Grade Ridership Study: Supplemental Details*, Exhibit B-4, 20 November 2002. Thousands of annual person trips. [b]Year 2000-2001 data. Thousands of annual person trips. See text. [c]Adjusted by the forecasted 7.48% growth in the market size between 2000 and 2010. Thousands of annual person-trips. See text.

Available population forecasts indicate the Tulsa and Oklahoma City market areas will grow by 7.48% by the year 2010.[11] Expanding the estimated number of trips by purpose for the 2000-2001 period by this growth factor yields a year 2010 Oklahoma City to Tulsa travel market of 3,172,483 annual person-trips. These calculations are summarized in Table 9.

Tulsa to Oklahoma City patronage forecasts

Eq. (1) can be applied to the trip estimates in the fourth column of Table 9 using the mode split estimate in Appendix B and the before and after service characteristics in Table 6 to develop an estimate of patronage on a high speed passenger rail line operating between Oklahoma City to Tulsa for 2010. To simplify the analysis, we consider only the auto and high speed rail modes. This approach seems reasonable given the small modal usage of bus and air service between Oklahoma City and Tulsa. Since none of the variables for the auto mode change, Eq. (1) simplifies to the form in Eq. (2) where the *r* refers to the rail mode, *a* refers to the auto mode, and the other terms are as defined in Eq. (1):

$$\acute{p}_r = \frac{p_r^0 \exp(\acute{V}_r - V_r^0)}{p_a^0 + p_r^0 \exp(\acute{V}_r - V_r^0)} \qquad \textbf{(2)}$$

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[9] County population, *Oklahoma State Data Center*, Oklahoma Department of Commerce (

[10] Florida Demographic Forecasting Conference (http://fred.labormarketinfo.com).

[11] County Population, ibid.

Table 10 shows the results of this procedure which yields a year 2010 forecast of 134,452 annual rail passengers, or 368 passengers per day.

TABLE 10 Patronage estimate for the Oklahoma City to Tulsa high speed passenger rail service for the year 2001using the WSA model for the Tampa to Orlando model

Trip purpose	w/o HSR rail trips[a]	Diverted trips	Induced trips	Total trips
Commute	4,495	11,950		16,445
Resident business	15,239	39,537	644	55,420
Resident non-business	7,492	18,417	289	26,198
Non-resident business	1,790	2,303	24	4,117
Non-resident non-business	7,492	24,312	468	32,272
TOTALS	36,508	96,519	1,425	134,452

NOTE: [a]Assumes a 1.12% rail mode split without the high speed passenger rail service. Taken from the Heartland Flyer mode split for 2001. See Appendix B.

METHOD 3: COMPARABLE CORRIDOR

In the U.S., operational high speed rail service exists only in the Northeast Corridor from Washington, D.C. to New York City. The characteristics of this corridor are too different from the Oklahoma City to Tulsa corridor to allow meaningful comparisons. The most comparable corridor in the U.S. for which detailed patronage forecasts have been prepared is the aforementioned Florida line linking the Tampa central business district with Orlando International Airport. Although not implemented, plans for this line specify a length of 84 miles and an average operating speed of 79 miles per hour.[12] Annual patronage is forecast to range between 453,000 and 582,000 in the year 2010.[13] The lower value is from Wilbur Smith Associates and includes only intercity Tampa - Orlando patronage on the "Beeline alignment" with stops at Orlando International Airport, International Drive, Disney World, Lakeland, and downtown Tampa. The higher estimate was prepared by AECOM Consulting for the same alignment. The proposed service would operate 365 days per year which translates into a daily passenger volume of 1241 to 1595.

The comparable corridor method scales a forecast taken from a control region, in this case the Tampa to Orlando corridor, to the subject region, the Oklahoma City to Tulsa corridor, using a *growth factors* procedure.[14] The aggregate data available for the Orlando to Tampa corridor suggests an adaptation of the *average factor* approach, shown in Eq. (3), is most practical for adjusting the Florida forecast to Oklahoma conditions.

$$T_{ij} = t_{ij} E \tag{3}$$

where

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[12] AECOM Consulting and Wilbur Smith Associates, *Investment Grade Ridership Study: Summary Report*, 20 November 2002, p. 12. Refers to Beeline Alternative.

[13] AECOM Consulting and Wilbur Smith Associates, *Investment grade ridership study: Supplemental details*,20 NOV 2002.

[14] Bruton, Michael J., *Introduction to transportation planning*, 3rd ed., UCL Press, London, 1985, pp. 137-143; Ortúzar, J. de D., and L.G. Willumsen, *Modelling transport*, 2nd ed., John Wiley & Sons, 1994, pp. 154-158.

T = trips from origin i to destination j in the horizon year
t = trips from origin i to destination j in the base year
E = growth factor, and

$$E = \frac{2010\ population\ in\ the\ Oklahoma\ corridor}{2010\ population\ in\ the\ Florida\ corridor}$$

The subscripts i and j refer to specific origins and destinations. Since only one set of origins and destinations exist in the Oklahoma City to Tulsa corridor, the direction of travel can be ignored. Each terminal will handle the same number of trips. Using the 2010 population data from Table 3, the growth factor is:

$$E_{OKC-Tulsa} = \frac{OKC + Tulsa\ 2010\ MSA\ populations}{Tampa + Orlando\ 2010\ MSA\ populations}$$

$$= \frac{1{,}113{,}900 + 838{,}300}{1{,}100{,}941 + 1{,}758{,}176}$$

$$= 0.6828$$

Applying this factor to the patronage range for the Tampa to Orlando line yields the high and low estimates for an Oklahoma City to Tulsa line shown in Table 11. These estimates need to be additionally adjusted for level of service. Fourteen trains will serve the Tampa to Orlando line compared to five trains in the Tulsa to Oklahoma City corridor. To effect this adjustment we make use of the pivot point model presented in the previous section. The patronage forecast produced in Table 10 assumed five trains per day. If fourteen trains per day were operated in the corridor the patronage forecast would be 238,551. The ratio of the patronage forecasts with five and fourteen trains per day is 0.564. The final column in Table 11 shows the patronage forecast adjusted by this train frequency factor.

SUMMARY OF FORECASTS FOR THE OKLAHOMA CITY TO TULSA CORRIDOR

Table 12 summarizes the daily passenger volume forecasted for the Tulsa to Oklahoma City HSR line developed using the three different methods discussed in this report. Note that the high forecast is more than ten times the low forecast. The high an low ranges can be further narrowed through collection of primary data and calibration of models specific to the Oklahoma City to Tulsa corridor.

Figure 6 displays the data in Table 12 graphically and in the context of the other HSR patronage studies we examined in the course of this study. The chart shows the regression forecast prepared as part of Method 1 bounded by a 95% confidence band. The interpretation of this band is that for any observed terminal area population, the HSR patronage forecast will occur within the band 95% of the time. For the 1.922 million people in the Oklahoma City and Tulsa metropolitan areas in the year 2000, no value between the upper limit of 4,449 passengers per day and the lower limit of zero passengers per day is any more likely than any other. The estimates produced by methods two and three are also shown in Figure 6 but are barely distinguishable since they are so close in magnitude. The band assumes this shape due to the potential for errors in estimating the constant term.[15]

TABLE 11 Year 2010 average daily patronage forecast for high speed rail service between the Oklahoma City and Tulsa metropolitan areas using the comparable corridor approach

	Unadjusted daily patronage	Daily patronage adjusted for train frequency
High Estimate	1089	614

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[15] Blalock, Hubert M., Jr., *Social Statistics*, 2nd ed., McGraw-Hill, 1979, pp. 422-423. Also, Hughes, Ann, and Dennis Grawoig, *Statistics: A Foundation for Analysis*, Addison-Wesley, 1971, pp. 329-331.

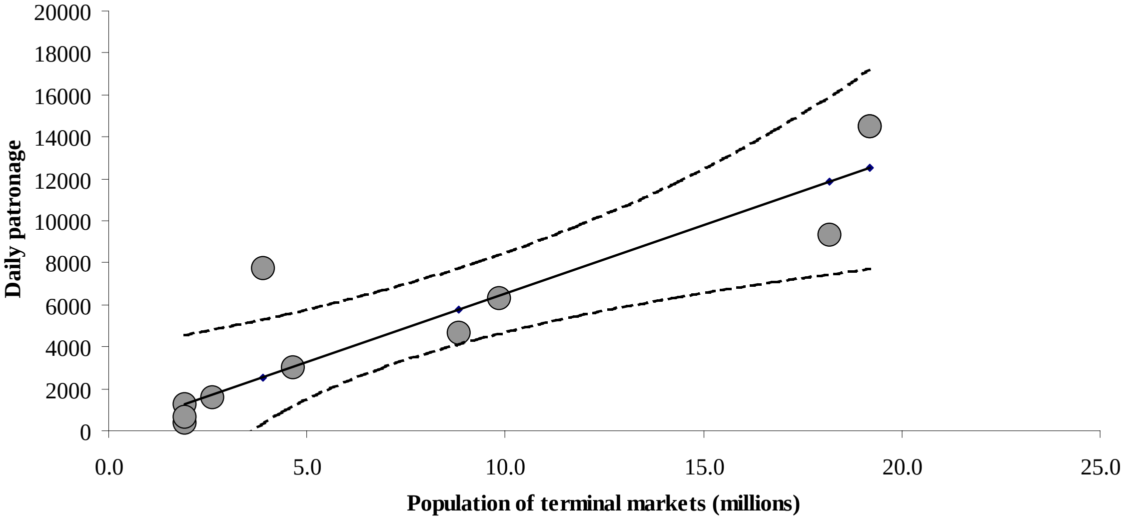
Low Estimate	847	477

TABLE 12 Daily passenger forecasts for the Oklahoma City to Tulsa HSR corridor using alternative methodologies for the year 2010

Method	High forecast	Medium forecast	Low forecast
Regression model	4,449	1256	0
Borrowed model[a]		368	
Comparable corridor	614		477

NOTE: [a]Forecast is for calendar year 2001.

FIGURE 6 Ninty five percent confidence band for the high speed passenger rail patronage forecasting equation *daily patronage* = 653.3 * *(metropolitan area population)*



NOTE: Observed data, denoted by filled circles (except for three forecasted values for the Oklahoma City to Tulsa line, population equal to 1.922), from Table 1.

APPENDIX A

SUPPLEMENT TO Figure 3

[SEE SEPARATE APPENDIX A FILE]

APPENDIX B Modal Share Analysis of Travel in the Oklahoma City to Dallas - Ft. Worth Market by Month for the Year 2001

Month	Heartland Flyer Patrons[a]	Auto Travelers[b,c,d]	Bus Travelers[e]	Air Travelers[f]	All Travelers	Rail Mode Split	Auto Mode Split	Bus Mode Split
Jan	1,231	137,109	750	18,662	157,752	0.78%	86.91%	0.48%
Feb	1,511	127,822	750	18,662	148,745	1.02%	85.93%	0.50%
Mar	2,929	170,597	750	18,662	192,938	1.52%	88.42%	0.39%
Apr	1,645	156,064	750	18,662	177,121	0.93%	88.11%	0.42%
May	2,173	176,376	750	18,662	197,961	1.10%	89.10%	0.38%
Jun	2,760	176,298	750	18,662	198,470	1.39%	88.83%	0.38%
Jul	3,410	190,181	750	18,662	213,003	1.60%	89.29%	0.35%
Aug	2,295	174,353	750	18,662	196,060	1.17%	88.93%	0.38%
Sep	1,750	158,149	750	18,662	179,311	0.98%	88.20%	0.42%
Oct	1,958	170,550	750	18,662	191,920	1.02%	88.87%	0.39%
Nov	1,708	173,989	750	18,662	195,109	0.88%	89.18%	0.38%
Dec	1,721	171,400	750	18,662	192,533	0.89%	89.02%	0.39%
Total	25,091	1,982,886	9,000	223,944	2,240,921	1.12%	88.49%	0.40%

NOTES: [a]SOURCE: Amtrak Intercity Chicago (provided by ODOT - Rail Programs Division). [b]Average monthly traffic. SOURCE: Derived from traffic counts taken at I-35/Thackerville permanent count station for January 1, 2001 to Dec. 31, 2001. SOURCE: ODOT Planning and Research Division. [c]Total average traffic for each month was divided into two axle and other vehicle categories using vehicle type proportions derived from vehicle classification counts taken Dec. 10, 2001, one-half mile north of Red River bridge. SOURCE: ODOT Planning & Research Division. [d]Trip reported refer to persons trips derived by multiplying the number of two axle vehicles by average two axle vehicle occupancy. SOURCE: Vehicle occupancy counts taken by R. Marshment on Februrary 5, 2003, on I-44 northbound at picnic area southwest of Wellston exit. [e]Interview with ticket counter personnel, Oklahoma City Bus Station, 5 March 2003. [f]SOURCE: Karen Carney, Will Rogers Airport, byFAX, 23 Jan 2002.

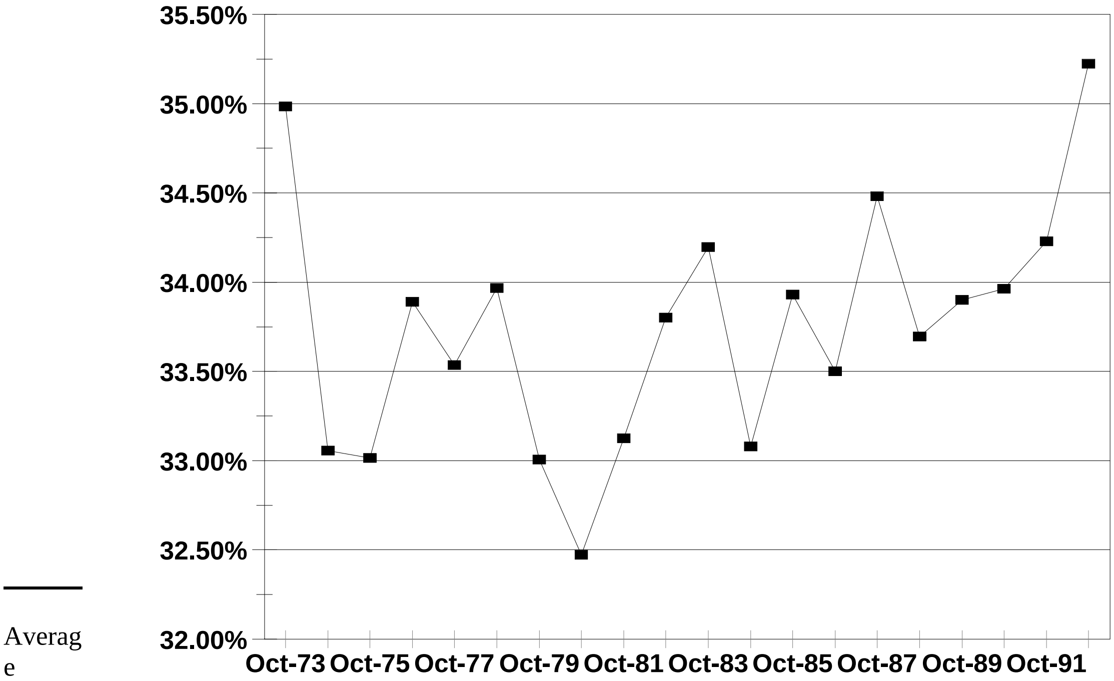
APPENDIX C Travel Time and Distance Measurements in the Oklahoma City to Tulsa Market

Date	Direction	Distance (miles)	Time (minutes)	Weather
25 October 2002[a]	eastbound	111	101[b]	light rain, fog
25 October 2002[c]	westbound	109	99[b]	heavy rain, fog, dark
5 February 2003[a]	OKC-TUL	106	105[d,e]	overcast, dry pavement
5 February 2003[f]	TUL-OKC	107	98[e]	overcast, dry pavement

NOTES: [a]Routing from Santa Fe Station (Reno and E.K. Gaylord) in OKC to Broadway to I-235 northbound to I-44 eastbound to I-244 eastbound (Tulsa) to 7th St. exit to Detroit Ave. to 1st St. to Tulsa Union Station at 1st St. and Boston. [b]Poor road conditions but able to do the speed limit most of the trip. [c]Routing from Tulsa Union Station (1st St. and Boston) to Heavy Trafficway to I-244 westbound to I-44 westbound to I-235 (OKC) southbound to Broadway to E.K. Gaylord to Main Street (eastbound) to Oklahoma St. (southbound) to Reno Ave. (westbound) to Santa Fe Station (at E.K. Gaylord). [d]Congestion due to accident at I-235 and N 50th caused a five minute delay. [e]Construction on access ramp to I-44 (Turner Turnpike) and multiple lane closures for construction on Turner Turnpike reduced the speed limit. [f]Routing from Tulsa Union Station (1st St. and Boston) to Heavy Trafficway to I-244 westbound to I-44 westbound to I-235 (OKC) southbound to 6th St. (westbound) to E.K. Gaylord (southbound) to Main St. (eastbound) to Oklahoma St. (southbound) to Reno Ave. (westbound) to Santa Fe Station (at E.K. Gaylord).

Appendix D

Percentage of Fourth Quarter Passenger Car Traffic on the Turner Turnpike (Oklahoma City to Tulsa) in the Month of October: 1973 - 1992



Average October Percentage (1973 - 1992) = 33.7525%.

APPENDIX A: SUPPLEMENT TO FIGURE 3

Figure 3 shows recent patronage forecasts prepared for eight proposed HSR lines for various U.S. city pairs plus a proposed line between Oklahoma City and Tulsa. Tables A-1 and A-2 lists the data and sources used to construct Figure 3. Table A-1 summarizes the characteristics of the systems studied. Table A-2 provides the population data and abbreviations used in Figure 3. Figure A-1 shows the proposed Florida high speed passenger rail system. Figure A-2 shows the proposed California system.

California Corridor

California High Speed Rail connects San Francisco, Sacramento, Los Angeles, and San Diego. All the HSR lines have the same north-south orientation with the exception of the HSR link between Fresno and Merced/Los Banos.

Florida Corridor

The proposed Florida high speed passenger rail system forms a triangle with terminals at Tampa, Miami, and Orlando. In the Tampa to Orlando corridor, intermediate stops include: (1) Lakeland, between Tampa and Orlando; and (2) Orlando attractions, which includes the Disney theme parks to the southwest of the City of Orlando. The line is anchored by Orlando International Airport and downtown Tampa. The Orlando location in Figure A-2 refers to the stop at Orlando Attractions.

TABLE A-1 Design characteristics of selected high speed passenger rail corridors

Line	Average Speed (MPH)	Distance (Miles)	Passengers per day	Trip Time (min.)	Intermediate Stops	Trains per day[2]
San Diego to Los Angeles[1]	151	151	14521	60	6	32
San Diego to San Francisco[1]	159	553	6301	209	18	32
Los Angeles to San Francisco[1]	162	402	30685	150	11	32
Los Angeles to Sacramento[1]	177	380	9315	129	9	32
San Francisco to Sacramento[1]	169	282	4658	100	9	22
Tampa to Orlando[3]	79	84	1241	64	3	14
Orlando to Miami[4]	143	246	7726	103	2	32[5]
Tampa to Miami[4]	132	319	3014	145	5	24[5]

SOURCES: [1]Trains per day includes only express and semi-express. California High Speed Rail Authority. *California High Speed Rail Business Plan. [http://www.cahighspeedrail.ca.gov/business_plan/]*, 1999, pp. 2-8, 3-4. [2]Not all trains make every stop in the California plan. [3]AECOM Consulting and Wilbur Smith Associates, *Investment Grade Ridership Study: Summary Report*, 20 NOV 2002, Exhibits 4-2 and 7-1. [4]Lynch, Thomas A. and Neil Sipe. *Travel Time, Safety, Energy and Air Quality Impacts of Florida High Speed Rail.* Florida State University, Center for Economic Forecasting and Analysis**,** June 1997, pp. 8, 20. [5]SYSTRA (French Consulting Firm), *Ridership and Revenue Study - Florida Overland Express: Draft Final Report,* Florida Department of Transportation, January, 1998, Figure 5.3, PART 5, p. 6.

TABLE A-2 Year 2000 terminal market populations and abbreviations for the high speed passenger rail lines shown in Figure 3

		Population in millions	
	Abbreviation	Central city	Metropolitan Area
Los Angeles	LA	3.694	16.373
Sacramento	SAC	0.407	1.797
San Diego	SD	1.223	2.814
San Francisco	SF	1.176[a]	7.039
Miami	MIA	0.362	2.253[b]
Orlando	ORL	0.186	1.645
Tampa[c]	TPA	0.303	2.396
Oklahoma City	OKC	0.506	1.083
Tulsa	TUL	0.393	0.803

SOURCES: All data from *American Factfinder*, U.S. Bureau of the Census, "factfinder.census.gov," unless otherwise noted. [a]Includes the cities of San Francisco and Oakland. [b]Includes only the Miami-Ft. Lauderdale PMSA. [c]Tampa market for proposed HSR service to Orlando includes only Hillsborough County with a year 2000 population of 982,000.

FIGURE A-1 Proposed Florida High Speed Passenger Rail Network

SOURCE: Adapted from Kane, Tom. *Florida Overland Express*, Florida State University. www.cefa.fsu.edu/FOX.html

FIGURE A-2 California high speed passenger rail network

SOURCE: Adapted from California High Speed Rail Authority Route Map.
www.cahighspeedrail.ca.gov/route_map/default.asp